TECHNICAL REPORT

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FACTORS IN DESIGN AND CONSTRUCTION OF A DEVICE FOR HEATING AND DISPENSING FOOD COMPONENTS

by

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DISPENSERS	FOOD (HOT)	QUALITY	PACKAGING
DISPENSING UNIT	FOOD (COLD)	KITCHENS	DIALS (OVEN)
FOOD DISPENSING	DESIGN	MICROWAVE HEATING	STORAGE
FOOD SERVICES	CONSTRUCTION	MICROWAVE OVENS	CHILLERS
	COLD STORAGE		

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The U.S. Air Force expressed interest in an untended Hot and Cold Food Dispensing Unit for missile site and off-hour food service.

A study of factors in design and fabrication of a unit for storing, heating and dispensing meal components and the evaluation of container materials has resulted in a feasible system and design concepts for equipment to provide high quality meals upon demand without need for a conventional

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) kitchen or food service personnel. A system involving microwave heating at 2450 MHz for thawing and rapid internal heating and Jet-Air surface heating for crisping and browning where needed has been demonstrated and a preparation time of approximately two minutes was shown. The system offers a choice of several entree, vegetable and starch items.

Packaging concepts for imcrowave only and microwave plus Jet-Air heating were evaluated and workable samples were made and tested.

FOREWORD

The U.S. Air Force expressed an interest in an untended hot and cold food dispensing unit which would provide high quality food service to personnel at remote locations. Although cold food dispensing presents no serious problem and can be handled by commercial refrigerated vending equipment, there is no commercial vending equipment which can heat and dispense complete meals rapidly enough to satisfy this need. This study was carried out to determine whether a feasible design could be developed to store, and then heat on demand a selection of meal components in two minutes or less without a sacrifice in food quality.

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UNTENDED FOOD SERVER UNIT

I. OBJECTIVES

The objectives of this project are to study factors in design and construction of a device for heating and dispensing food components and to evaluate containers and materials for use in the device to determine feasibility and then, if deemed feasible, to present general design concepts of an untended meal service unit.

II. INTRODUCTION

The U.S. Air Force has expressed an interest in an Untended Hot and Cold Food Dispensing Unit for missile site and off-hour food service. In order to develop a design for such a unit the foods, packaging, transport, storage, selection, retrieval, heating, dispensing, and many other interrelated aspects were considered. The aesthetic importance of food quality and attractive presentation were emphasized and a time frame of two minutes from selection to serving was specified for this on-demand food service.

The procedure followed to accomplish the objectives was to study available heating means, packaging materials and equipment. Then compatible elements were selected and combined into a system. The functions of the system were simulated and evaluated, and the general concepts were drawn into the general concepts of equipment.

III STATE OF THE ART REVIEW

A. HEATING MEANS

Methods of surface heating of foods currently in wide usage include infra-red, or radiant heating; deep-fat frying, conductive container (17); hot air whether still, convection, or impingement; steam at atmospheric or higher pressure; and hot surface or grilling.

Internal heating of foods is accomplished by resistive, induction, or microwave heating. Infra-red is widely used alone or with another heating means. Tappan and Westinghouse oven manufacturing used infra-red with their microwave ovens earlier than 1966 and Bomar Manufacturing Company produced a microwave oven in which a hot radiant rod acted as an antenna for the microwave energy input as well as acting as a browning device. The heating elements employed to produce infra-red heat include:

1. Gas heated radiants
2. Electrically heated coils and rods
3. Quartz plates with submerged electrically heated resistance wire
4. Quartz tubes with electrically heated elements
5. Semi-conductive glass or metal plates heated directly by applied electrical potential

Infra-red can produce a high enough temperature to crisp and brown food surfaces within two minutes. This rapid surface heating is effective for searing a steak or hamburger, but less effective for crisping and browning fried chicken or other irregularly shaped products or stacked products such as french fried potatoes.

Deep-fat frying provides relatively uniform surface heating and generally good browning and crisping. This is also the primary method of producing the fried foods so popular in this country. However, the sanitation requirements of a deep-fat frying operation such as oil filtration, crumb collection, spatter and spillage control make this method of heating more dependent on regular and frequent cleaning than the other means of heating foods. In addition, fat aerosols permeate surrounding areas with stale and rancid odors, and this has presented a serious problem with use of automated food service machines such as automatic popcorn poppers.

The conductive container method of heating food is exemplified by the Integral Heating System developed by Three M Company (17). Heating occurs as an electric current is applied directly to a two-part container. Heat transfer to food is accomplished by conduction or vapor migration and condensation within the package. This method offers convenience in readying a variety of meals simultaneously. It does not appear practical for heating foods within two minutes since heat is necessarily applied to the surface of the product.

Induction heating provides deep heating at less cost than microwave because available generators produce energy more efficiently. However, presently evident equipment does not have the tolerance for heating widely variable food portions.

Resistance heating is also very effective in some applications, but not highly versatile. This means of heating can heat the interior of food and can be very rapid. Uniform product resistivity and means of making thorough contacts are required. Direct resistance heating of food portions does not appear practical for this project.

Steam heating can be the most rapid means of applying energy to food portions. Saturated steam heats particulate foods like green peas and green beans very effectively, but is limited to the top surfaces of sauces and larger pieces. Steam is effective in controlling surface drying. In some equipment superheated steam actually dries slightly to compensate somewhat for the moisture of condensation that occurs in the initial heating. Very rapid food portion heating is accomplished by pressure steam heaters. In some food heaters, steam jets are combined with increased pressure to give very rapid heat transfer. A conveyorized system of steam heating trays of food is marketed by German Vosswerke. However, the initial cost of a pressure-steam-heating system is large, the enclosures required are costly, and the food handling requirements complex.

The use of atmospheric steam for heating food portions should be considered in this study. Atmospheric steam may be generated within a closed package by application of external heat, or by internal application of hot water vapor. The hot water vapor may be well above boiling temperature and still contribute moisture to the cooler food mass as it condenses. Further, the hot water vapor at higher temperatures can be applied to obtain crispness, browning, and searing.

Hot surface heating, or grilling, is simple in application and heat control. However, heating through a food container places high temperature requirements on the container. Also, the possibility of burning the bottom surfaces before the centers are heated exists in some foods. Like infra-red heating, the high energy level heat source tends to burn exposed parts before other areas are heated.

Microwave methods produce deep heating which provides rapid and uniform thawing, as well as rapid heating of the interiors of the thawed foods. This rapid deep heating is accomplished without overheating outer surfaces and can be designed to heat centers of portions within two minutes time. This is an advantage because it is undesirable to brown or dry many of the foods specified in this study when they are heated for serving.

Some others of the specified foods require surface crisping and browning for serving to develop freshness of flavor and aroma as well as the crisp texture associated with good food of this type by the consumer. The proper flavor, aroma, and texture is conventionally obtained by baking, frying, or grilling at considerably more time than the two minutes specified for automatic service.

This requirement for crisp, browned surfaces needs additions to the heat input of microwave. Infra-red and convection ovens have been used commercially along with microwaves, and deep-fat frying within a microwave field has been evaluated for food service by several laboratories and used commercially for products such as doughnuts (16). Recycling hot air oven combined with microwave has been applied by Microaire (U. S. Patent 3,514,476). This oven requires 500 to 550°F. temperatures to provide crisping at speeds to match microwave. One method of surface heating which covers most surfaces of foods and crisps and browns within two minutes is the hot air impingement oven. This oven, which utilized the "Jet Sweep" principle, was developed and patents applied for by D. P. Smith (U. S. Patent applied for). This oven directs jets of high velocity air at the surfaces of the food portion and its container to give rapid heat transfer and can give crisping, browning, and searing textures and flavors within two minute's time at air temperatures of 370 to 450°F.

B. PACKAGING

Packaging for the Untended Food Service System was evaluated according to the factors mentioned above concerning:

1. Protection of food in storage
2. Mechanical support and shipping
3. Suitability to desired type of heating
4. Convenience of uncovering, both in jet crisping and in serving
5. Appearance as a serving container

1. Materials:

The packaging materials most practical for consideration included plastic, paper, glass, metal, and ceramics, the most commonly used materials for food packaging. Because both microwave transparency and resistance to high heat were required, many materials were investigated. A list of those considered may be found in Appendix A.

The problem of obtaining suitable packaging for products heated from frozen to serving temperature was discussed by Levine (24). He noted that although aluminum is excellent for frozen storage, it is microwave reflective, and that coated or laminated board seemed promising for packaging of convenience foods. He also described other materials and designs used successfully in microwave, among them being Pyroceram, glass, high temperature plastic, and film laminations in the form of pouches.

Glass and glass-ceramics, including Pyroceram, were described by Payne and Dann (25) as being microwave absorptive, although relatively transparent. This characteristic renders some forms of glass and glass-ceramics unsatisfactory because rapid absorption in localized areas can cause breakage. The less lossy low expansion glass or ceramic materials make good permanent ware for microwave use. Although most of the microwave acceptable glass and glass-ceramics containers are too expensive to use as disposable items, a ceramic dish has entered the market as disposable (24). Glass and glass-ceramics have the advantage of withstanding the high temperatures necessary for crisping and browning and may be suitable for storage and automatic selection, heating and serving, if associated with a kitchen and dish washing operation.

High temperature plastics include engineering plastics as well as those developed for food applications in high heat environments (35,36). Films for lids and pouches and dishes formed from high temperature resins were included (20). These materials offer advantages in cost, microwave transparency, and disposability. However, although they withstand higher temperatures than other plastics, only a few will tolerate temperatures high enough for crisping and browning. These are the engineering plastics used primarily for aerospace, electrical, and mechanical applications. A number of other applications have been found for these plastics, including the preparation of high temperature paper laminants. Some aromatic compounds and some heterocyclic compounds are stable at 500, 800 or 900°F. (Appendix A). These few seemed to offer the possibility of making a dish that could go from frozen storage to heating to serving. The high temperature plastic materials which may be useful in food equipment and food packages are reviewed in Appendix A.

Plastic films combined with cellulose boxboard present many packaging possibilities. In some instances, the film is thermoformed to make liners for boxboard containers. This offers the advantage of leak-proofing (19). Boxboard, available both uncoated and with polyethylene and polypropylene coatings, was the lightest in weight, least in cost, and the most completely disposable of the materials under consideration. A wide variety of configurations is available, including some that are leakproof. The polyolefin plastic coatings provide good storage protection, however they do not withstand temperatures necessary for crisping and browning foods. Pulp boards and boxboards have been developed for oven use at temperatures up to 400°F. A liner made from high temperature resins used with high temperature board can combine low cost and rigidity advantages of paper containers with moisture protection and the resistance to high heat needed for food browning and crisping.

2. Container Forms:

Individual portion containers were surveyed to find a package form in which the food could be frozen, stored, heated, dispensed and served. Trays, bags, boxes, and combinations of these were considered.

Trays are in the widest use for individual portions. They are available in a wide variety of plastics, foil, and cellulose boards. Some have lids and others are overwrapped with plastic film, waxed paper, or hooded with foil. Shrink wrap films form quite tight covers. Many trays are marketed in cardboard boxes for display printing and mechanical protection.

Bags for frozen storage of foods and for heating in microwave or boiling water are currently in use, and bags are available that can withstand aseptic packaging methods (20). However, bags do not represent a popular means of presenting individual food portions to the consumer. Use of bags for frozen storage appears functional and inexpensive for automated systems. For untended food service, the mechanical problems of automatically opening the bags and transferring to serving dishes outweigh the package advantages. If the consumer ate from the bags, as in space feeding or some field food service, pouches or bags should be considered.

Telescoping and one-piece boxes provide the advantages of trays as well as rigidity for stacking. Boxes for food portions are primarily used for carry-out foods. The box concept however, adapts readily to use for individual portions, as seen in Appendix B.

C. SPECIAL PACKAGING DEVELOPMENTS

The rapid growth of fast food service has stimulated many new packaging developments (20,28) for packaging individual portions.

Aluminum foil is a material used widely for pre-portioned foods. However, since it is microwave reflective, it is usually not considered for microwave cooking.

Foil trays with removable, heat-sensitive or microwave-transparent lids may be useful for some portions in this system.

High temperature plastics have been used to give full microwave transparency. Polyester, melamine, and polysulfone have been used for trays intended for use in either microwave or hot air ovens. These packages may go from freezer to heating to serving, but are expensive at present.

Also effective at higher temperatures and suitable for limited storage, heating, and serving are specially processed wood fiber pulp trays. Trays of this treated pulp board are designed to be self-venting and heat-sealable with coated board or film covers, and are good for microwave and conventional ovens. Overwrap or cartons to retain moisture will be required if pulp trays are used for storage.

Box board that can withstand temperatures in the 350 to 450°F. range is under development. Packages made of coated or laminated board currently on the market are leakproof, offer good storage protection, and work well in microwave. However, the coatings are not appropriate for high temperature usage.

One combination package form consists of a die-cut board container with a thermoformed plastic liner. It was first used for butter. It was designed to be used without heating or cooking, however, it may be filled at 90°C. The rigidity of the board allows use of thin plastic film which reduces cost. Current uses include packaging of marmalade and pickled herring as well as butter and margarine. (19)

A problem peculiar to microwave cooking is the overdrying and charring of the thinner outer edges of foods of high liquid content. The technique of using metal to reflect the microwave energy shields the food and permits limiting or completely preventing the microwave heating in selected areas of a food portion. Appropriate heating of various portions in a complete meal is accomplished by using a properly perforated metal cover into which the package fits while cooking. (22) (U.S. Patent 3,615,713). Various configurations of reflective metal shielding are applied to food products by incorporating foil cups or foil wrappers in the packaging. (15) (U.S.Patent 2,714,070).

"Integral Heating", discussed above, makes the serving dish the means of heating. Heating is accomplished by passing electric current from the oven to the two-part dish in which the individual meal has been placed. The two parts of the dish consist of a plastic outer dish and a glass ceramic inner dish. Current is pulsed from the oven to metal buttons on the outer dish, then to resistors on the inner dish. The heated dish heats the food, taking eleven minutes from frozen to serving temperature.

D. NUTRITIONAL AND AESTHETIC QUALITIES

Good food quality necessarily includes consideration of retention of nutrients as well as the aesthetic effects of the sight, texture, and taste of the food.

The manner in which foods are processed, stored, and heated affects the retention of nutrients as well as the aesthetic aspects. The heat applied to foods during processing and cooking has both beneficial and undesirable effects. Cellulose in vegetables and structural proteins in meats are softened during processing and heating, which renders these foods more tender and more digestible. Flavor and texture are altered during cooking which enhances palatability. However, loss of water soluble vitamins and degradation at high temperature in presence of oxygen of fat soluble vitamins, (10) are liabilities nutritionally of heating. In addition, overheating of protein and overbrowning result in undesirable products.

Dehydration of foods for storage serves the purpose of reducing the available water in a food as protection against food spoilage by microbiological organisms. The nutritional loss in dehydration and storage can be considered in two classes as stated by Labuza (8); of the process itself; and the interaction between compounds produced during storage or drying and nutrients.

Volume feeding includes the treatment of raw material and the preparation and service of food products as well as heating and storage. These also need to be considered in the loss or retention of nutritional value as well as aesthetic quality.

Raw materials are usually purchased fresh, canned, dried, or frozen. Length of time and temperature as a storage condition affect nutritional quality, with the amount of nutrient destruction rising with the temperature of storage. Generally, retention of nutrients is good in frozen storage providing sufficiently low temperature is maintained and packaging provides adequate moisture protection. Larger containers or packages also show larger nutrient losses as longer processing time is required for the greater quantity.

The method of thawing frozen items is a factor in aesthetic quality and safety as well as nutritional quality. Livingston, et al (9) described the four most commonly used thawing methods as ambient temperature thawing, thawing at refrigerated temperatures, thawing in running tap water, and direct cooking thawing, and commented that slow methods of thawing result in exudation. Attempts at rapid thawing of large frozen items frequently result in deterioration of the exterior before the interior is thawed (9). This also results in loss of aesthetics.

Microbiological growth is favored by long standing periods in the temperature range of 40° to 140°F. While the thawing process is not usually the culprit in food poisoning, parts of a large item in the process of slow thawing are susceptible because of standing in the above temperature range. Nutritional quality is also affected by long standing periods due to oxidation and leaching of nutrients in water.

Cooking is a major factor in nutrient loss because of the susceptibility of some nutrients to heat and oxidation. Loss is greater with long exposure and high temperature. Large batch sizes and slower heating methods contribute to deterioration of some nutrients by length of time exposed. Livingston et al, (9) noted marked reduction of Vitamin C loss with the substitution of continuous steam cooking for boiling of vegetables. Electronic cooking lessens the length of time of exposure by faster cooking. Livingston, et al, (9) cited studies indicating that nutrient retention was approximately the same for electronic cooking and good conventional cooking. Boiling,braising, and simmering are among the practices that involve long exposure to heat, and roasting and frying are methods that produce high temperatures.

Holding food products prior to service for extended lengths of time in steam tables, bain-maries or infra-red food warmers can result in lessened food quality. The length of holding time, the holding temperature, exposure to light, and aeration affect the nutronal quality as well as the aesthetic quality. (9).

Lack of data on mass feeding practices and the preservation of high nutrient content of food products suggests that more research in this area is needed. However, methods of food handling which include quick freezing, storage at low temperatures and the shortest exposure to high temperatures favors retention of nutrients. These same factors generally result in better taste, texture, and appearance of food.

IV TEST PROGRAM AND RESULTS

A. OUTLINE OF TEST PROGRAM

The test program was planned to find both quantitative and subjective information to determine whether the objectives of the specification and description were feasible and then to obtain data for use in conceptual design of the proposed untended hot and cold food dispensing unit.

1. HEATING MEANS:

Since the heating of food is the most critical function in this unit and the heating means largely determines both the packaging and the equipment design, these tests preceded others.

First, general calculations of energy required for heating the different portions were made using data originally determined for freezing similar food products.

Second, the capability of available microwave ovens to provide sufficient heat was determined. These tests quickly showed that rated energy output of ovens did not necessarily provide the rated heat input to the various food portions. A method for measuring energy input to various sized food portions was developed.

Third, actual samples of representative food portions were heated in available microwave ovens, and means were developed to measure representative serving temperature obtained.

Fourth, after microwave heating conditions were generally determined, surface heating by Jet Oven impingement air was applied to those food products which needed crisping or browning. The proper combination of microwave and Jet Oven heating combined to give proper product temperature and surface condition was determined.

2. FOOD HEATING:

Selected portions of various foods were heated in microwave to obtain the 140 to 160^{o}F. minimum serving temperature specified.

Portions which required surface crisping or browning in addition to microwave were heated to determine whether acceptable food quality for serving could be obtained.

3. PACKAGING:

Packages of many types were tested for microwave heating, Jet Oven heating and for product handling and storage. Packages were obtained from many commercial sources and others were hand-made from special materials.

The sizes and shapes of available packages and trays and the dimensions required to handle the six-ounce entree and three-ounce vegetable or starch portions were also studied.

The need for and the effects of metal foil shielding of mixed food portions was considered to determine practicability of heating a complete meal of three portions at one time.

4. EQUIPMENT:

After heating and packaging tests suggested promising heating means and package size and construction, concept design of storage, selection, retrieval, heating and serving equipment was laid out.

Simulation and testing of specific components of the equipment was undertaken. A full scale "stack and lift" section for storage and delivery was tested with commercially packed vegetables in a -20° freezer. Samples of individual food portions of the specific foods mentioned in the specifications were packaged, frozen, and then heated and observed for food quality.

B. TESTING AND RESULTS

1. HEATING:

The means of food heating is one of the key technologies of this project. Analysis of the food heating methods available and the requirements of this project restrict food heating to the fastest methods of heating which are steam, microwave, and surface treatment by directed hot air.

Steam, as a primary heating means, is rejected for the Untended Meal Service because it is not sufficient for heating thick frozen food sections in the time available and because of long standby periods and mechanical problems involved. Steam as a secondary heating means inside individual packages is very important in some foods, and its effect was included in planning the heating phase of the

Untended Meal Service.

Microwave heating gives the only known means of heating the interior of thick frozen food portions in less than two minutes and the flexibility of heating a wide variety of compositions and shapes of food materials. The effectiveness of available microwave ovens in applying both amount and proper distribution of heat was studied.

It is evident that a microwave oven does not always put its stated wattage output into every portion. In addition, ovens currently in use are designed to accommodate large loads as well as individual portions. It is necessary to evaluate the actual power input to food portions in order to determine whether the microwave ovens will meet the requirements of this project.

a. <u>Power Output Versus Portion Heating</u>

Present methods of measuring power output include:

Electronic watt meter

Temperature rise in quantities
of water from 1 pint to 2 quarts

These methods of measuring the energy intake of one size sample provide no information about the output of the oven to samples of various size. In order to obtain this data, a curve showing available power was prepared. The points on the curve were found by heating 2, 4, 6, 8, 12, and 16 ounces of water for a fraction of a minute. The temperature change between the initial temperature of the sample and its temperature after heating was used to calculate the amount of energy in Btu per minute absorbed by the sample. Figure 1 and Figure 2 show the results of these tests. The curves show a marked reduction in energy input into smaller portions, although temperature rise was higher. The data obtained for various ovens, sample calculations and calorimetry techniques used may be found on pages 65-90 of Appendix B.

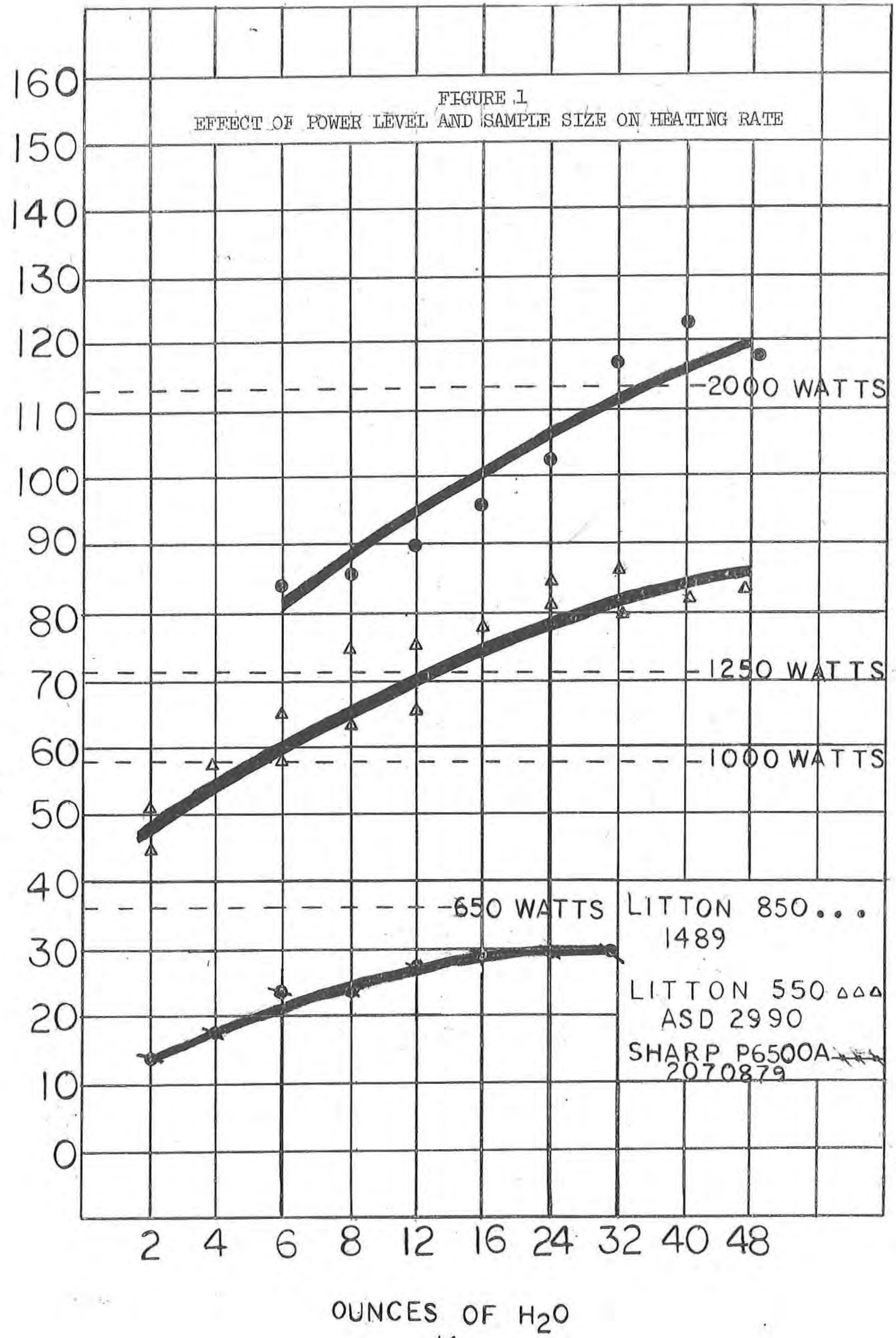
FIGURE 1
EFFECT OF POWER LEVEL AND SAMPLE SIZE ON HEATING RATE
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
BTU/MIN
2000 WATTS
1250 WATTS
1000 WATTS
650 WATTS
LITTON 850 . . .
1489
LITTON 550 ΔΔΔ
ASD 2990
SHARP P6500A
2070879
2 4 6 8 12 16 24 32 40 48
OUNCES OF H2O

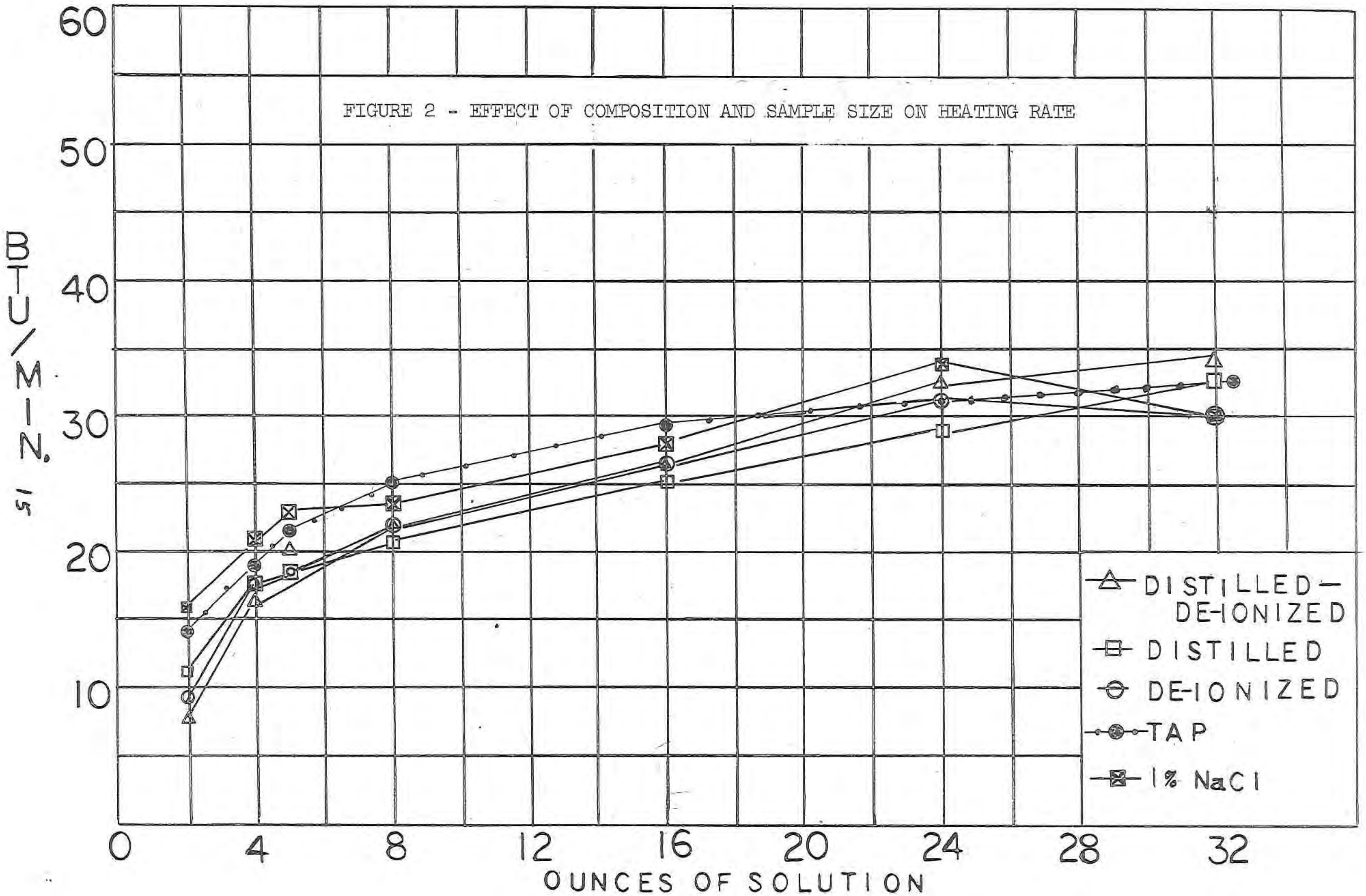

FIGURE 2 - EFFECT OF COMPOSITION AND SAMPLE SIZE ON HEATING RATE

A standard method of preparing the water samples and measuring the temperature change was developed to insure accuracy. The major problem in maintaining accuracy was avoiding evaporative heat loss. Both of the methods used are discussed in greater detail on pages 73-79 of Appendix B. The preferred method was accomplished by weighing the water samples into polyethylene bags having a bottom gusset. The bags were heat-sealed. Heating and temperature measurements were done in a styrofoam box with 1½-inch thick walls equipped with a tunnel, so the thermometer could be placed through the tunnel of the box, between the flaps of the bag gusset, and be read from outside the box. The sample was placed in the box, the thermometer arranged in place, and the initial temperature noted. The sample, still in the box but without the thermometer, was then heated. When the sample was removed from the oven, the thermometer was replaced and the final temperature noted. This technique offered the advantage of keeping the sample insulated at all times, thus reducing evaporative heat loss and insuring against effects of ambient temperatures. The insulated cover reduced external heat effects and permitted measuring equilibrated temperatures in the water load. The water load could be agitated to obtain representative temperature of the whole water load.

b. Calculation of Heat Input Requirements

A means of calculating the time required to heat a given weight of a food at a specific stored temperature to a desired serving temperature was needed. Published data on heat content of foods at various temperatures during freezing and the calculations used for calculating freezing capacities were used to calculate estimated heat requirements for serving. (Appendix B page110) Table 1 shows some calculated times and energy inputs in Btu. The theory was tested by calculating the time required to heat appropriate portions of the foods specified in this project at the predicted heat output of the selected microwave ovens and then actually heating portions for the indicated length of time. (Appendix B) Food samples were contained in a variety of packages, including bags and trays. A Litton 550 microwave rated at 1250 watts output and a Sharp R6500A oven rated at 650 watts were used for the heating. A check of the calculated Btu put into a food portion indicated that the theory was reasonable but not highly precise. The calculated heating times produced approximate results, but heating instructions for each portion must be refined by repetitive testing and adjustment. It was hypothesized that the water content of the ingredients of the entire portion is a major factor in calculating time requirements and that published data was for products with different moisture content where some of the variations were apparent.

c. Temperature Measurement Inside the Microwave Field

The technique of measuring temperature inside the microwave field evolved as the need for a more direct means of observing temperature changes was noted. (Appendix B page 91). For this procedure, a pyrometer-thermocouple was used. The thermocouple, sheathed in teflon tubing was inserted into the cavity and placed directly into the sample under consideration. The heat change was observed directly on the pyrometer face. This allowed the time or the temperature to be used as an end-point.

The results of testing involving measurements inside the microwave field suggested that refinement of the technique was needed. However, these tests showed that the size of food portions specified for this project could be heated from refrigerated temperatures 25^{o}to 45^{o}F. to 160^{o}F. in less than two minutes in existing microwave ovens. The pyrometer did not give accurate product temperature but it followed the rate of heating sufficiently to indicate when heating should stop.

The final test (Table II page 19) established that most of the specified portions of the foods for this project could be heated from frozen (-20^{o}F. to 0^{o}F.) to serving temperature (140^{o}F. to 160^{o}F.) in two minutes or less at 1250 watts of power and in ovens which were not designed for maximum efficiency in heating small portions. Portions were close enough to specified serving temperatures to verify that refined times in suitably designed microwave ovens could consistently heat the portions satisfactorily.

Surface heating using the Jet Ovens at 425^{o}F. gave crisp fried chicken and French fried potatoes in 1-3/4 minutes demonstrating capability of surface finishing within two minutes for these products if they were properly prepared.

TABLE I

ENERGY TO HEAT TO SERVING

PRODUCT	PORTION WEIGHT (Oz)	INITIAL TEMP. (°F)	BTU REQ.	HEATING RATES			TIME CALCULATED		FINAL TEMPERATURE OBSERVED (°F)
				OVEN RATING WATTS	OVEN RATING BTU/MIN	GRAPHED* BTU/MIN	OVEN RATING (Min)	OBSERVED RATING (Min)	
ROAST BEEF	5	35	27.67	650	37.14	18	.74	1.58	164
ROAST BEEF	5	0	62.54	650	37.14	18	.32	3.55	175
ROAST BEEF	5	35	27.67	1250	71.42	51.5	1.86	.53	150
ROAST BEEF	5	0	62.54	1250	71.42	51.5	.82	1.24	166
GREEN PEAS	3	35	17.03	650	37.14	15.0	.99	1.13	186
GREEN PEAS	3	0	39.19	650	37.14	15.0	.43	2.67	190
GREEN PEAS	3	35	17.03	1250	71.42	46.0	2.70	.37	182
GREEN PEAS	3	0	39.19	1250	71.42	46.0	1.17	.87	186

*Btu input to water load equivalent to water content of food portion

TABLE II

ENERGY TRANSFER IN SHIELDED TO NON-SHIELDED PORTIONS

Placement of Cups in Oven

3 oz. water in 16-oz foam cups

30 seconds in 1250-watt oven

Cup Designation	Beginning Temperature °F.	Final Temperature °F.	ΔT	Total Heating Calories
All cups Covered With Mylar				
A	61.5	109.5	48.0	
B	61.5	111.5	50.0	
C	61.5	98.5	37.0	
D	61.5	103.0	41.5	176.5
Cups A & D Covered with Foil Cups B & C with Mylar				
A	59.5	61.5	2.0	
B	59.0	141.0	82.0	
C	59.0	126.5	67.5	
D	59.0	60.5	1.5	153.0

2. FOOD HEATING:

The utilization of the steam generated within a closed package during microwave heating performed three functions:

1. Reduction of surface drying

2. Better distribution of heat through food portion

3. Reduction of energy loss by escape of steam

These result in better texture in moist foods and more thorough heating within the specified period. Energy loss by escaping steam can dissipate microwave energy and cause variable heating of similar portions if packaging closure varies. Foods that normally have a crisp texture require different heating. Crisping and browning reactions provide not only the expected texture but also desirable flavor development. Testing indicated that microwave heating alone did not produce acceptable results for those foods which are usually freshly baked or fried before serving. The use of properly directed impingement (Jet) hot air in conjunction with microwave was found to produce the desired surface heating to give crispness and browning within the two-minute period.

Initial testing of foods consisted of heating samples of certain of the specified foods by microwave and noting temperature, surface and interior texture, tenderness and color (Appendix B page 122). The meats tested were chopped sirloin, ground beef and fried chicken. Vegetables included were green beans, broccoli, and creamed peas and carrots. The starch items were canned new potatoes, crinkle-cut French fries, formed potato puffs and frozen stuffed potatoes. The results of these tests pointed to the major areas of needed improvement stated above. These were: difficulty in obtaining thorough even heating; the prevention of drying and overcooking of thin edges of foods, especially those with sauces or gravies; and lack of browning and crisping. Testing concerned with areas other than food quality per se often contributed information or confirmed conclusions drawn from food quality test results.

UNIFORMITY OF HEATING:

Uniformity of heating in microwave appears to be related to shape, consistency and initial temperature of the product as well as product composition. Green peas and mashed potatoes were selected for testing of shape and consistency because of the small round configuration of green peas and the foamy texture of mashed potatoes (Appendix B page 152). Mashed potatoes also could be shaped. Heating from frozen in a closed package resulted in the generation and entrapment of steam within the package, and test results showed that the steam was useful in distributing heat, especially in products of a different shape or texture. Other tests involving packaging and design confirmed this as well as showing that retention of steam was helpful in maintaining acceptable texture in high moisture content foods. (Appendix B, pp 152-155).

Applying microwave energy in pulses was tested in the thawing of frozen beef portions (Appendix B page 99). This was found to produce less outside cooking during thawing. Similar tolerance can be obtained by balancing energy input rate versus load in the oven, but time available in on-demand food service seriously limits thawing time.

Agitation of the product by stirring has been a classic method of distributing the heat in a cooked product. In products with sauces or gravy agitation was achieved by heating the product from frozen, then inverting the portion before serving (Appendix B page 153). Turkey, dressing, with gravy, and beef with gravy were packaged, frozen, and heated for two minutes. The packages were inverted just before eating and the resultant product was attractive and the heat uniformity was good. When the portion was packed and heated so that the liquid portion was on the bottom, turning the package over had the effect of pouring the liquid over the food as though the portion had just been plated.

EDGE PROTECTION:

One effect noted regularly was the overcooking and resultant drying and charring of thin or protuberant edges of products while the main food mass is reaching serving temperature. This effect reduced food quality because of resultant undesirable flavors, appearances, and textures. Irregularly shaped food portions such as fried chicken wings are also vulnerable to overcooking on the thinner edges. Protruding or angular edges absorb microwave energy much faster than the food mass because of their exposure and lack of heat capacity. These edges become dry and hard as the rest of the portion cooks to a desirable texture. Aluminum foil covering the affected part acts as protection by reflecting the microwaves. Energy enters the unshielded food mass, and the shielded area is cooked by heat transfer from the food mass. Inverting the tray before serving, and shielding with aluminum foil were methods tested for correcting the condition of overcooked edges. Proper package size to reduce thin edges is important, too.

Inverting the package as described above was found to be effective by mixing overheated liquid edges, such as sauces or gravies, when the edge drying effect was not extreme. Inverting the package also had the effect of discarding the small offending section of the portion because it remained in the bottom part of the package to be discarded when the portion was served inverted. (Appendix B page 153).

An aluminum foil tray was modified by removing part of the bottom and replacing with heat resistant plastic film (Appendix B page 134). Salisbury Steak with gravy was heated in this tray and an identical sample was heated in a tray of melamine, and the two steaks were compared. Edge drying was noticeably less in the modified aluminum tray.

Additional methods of shielding tested were edging a melamine tray with aluminum foil (Appendix B page 130) and preparing a foil bag with windows in both sides. (Appendix B page 132). Of these two methods, the foil bag was superior. Knowledge of the behavior of microwave energy during the heating process suggests that shielding one part results in additional energy input to the remainder of the item being cooked.

Four styrofoam cups were filled with the same measured amounts of water, covered with heat resistant film and heated in a 1250-watt microwave oven. The initial and final temperature of the water in the cups was noted. Then two cups were shielded with aluminum foil, and the four cups heated. Care was taken to place each cup in the same position in the oven. The initial and final temperatures were noted and compared. The results may be found in Table II.

The results show that total energy applied is reduced if part of the food load is shielded; also that a significant amount of the energy was referred to other portions. Thus if one portion of a three-component meal is shielded, the heating time of the total meal needs to be reduced from the time required to heat a non-shielded meal.

Heating frozen dinners, with portion wrapped in aluminum foil demonstrated the capability to heat an entire meal giving each portion varying amounts of energy (Appendix B page 119). One frozen dinner was heated without foil as a control. The results of this test showed that the portions in the dinners with one shielded portion reached a higher temperature in the same length of time than portions of the control dinner did. The portions wrapped in foil remained completely or partially frozen. Portion and sizes of openings in the foil shields can direct and vary the amount of microwave heating.

BROWNING AND CRISPING:

Browning of foods produces not only expected color but also flavor development. The lack of these qualities constitutes a major limitation in microwave cookery. Certain foods such as fried chicken and French-fried potatoes are not optimum quality unless they are crisp. The moisture migration from interior to outer layers characteristic of microwave heating makes adequate preparation of crisp foods by microwave difficult. This problem was solved in the system by the application of external heat from Jet Air impingement in conjunction with microwave. The moisture migration then served to produce a high quality interior texture while the external heat produced a high quality exterior texture with crisping and some browning.

This optimum texture for interior and exterior was exemplified in tests using fried chicken as the food sample. These tests involved a variety of packaging. In one test (Table III) the chicken was heated with microwave and Jet Air impingement simultaneously for one minute 28 seconds calculated as described in the section concerning heating tests in this chapter. (Appendix B page 110) The results were reheated fried chicken with a crisp exterior and moist interior.

Biscuits are good representatives of baked products and have been used extensively in testing, some of which was conducted in the course of other projects of the contractor. In some tests biscuits were cooked from the raw state with microwave then Jet Air impingement, and in some the biscuits were baked from raw with simultaneous microwave and Jet Air impingment. The lengths of time the biscuits were cooked ranged from 45 seconds to 2 minutes. In one test, biscuits reached internal temperatures of between 180 and 190 in one minute. (Appendix B page 141) The resultant products were characterized by a very thin crust and a fully expanded interior, as the dough was expanded by the microwave until the hot air started crust formation.

Potato products such as French-fried potatoes, and formed potato puffs were tested for color development and exterior texture. (Appendix B page 104) Test results indicated that 1 minute in a 1250-watt microwave oven was sufficient to heat 3-ounce samples of these products to approximately 180°F. Other tests showed color development to be slow, but textures were satisfactorily crisp when 1½ minutes of 425°F. Jet impingement hot air was applied.

TABLE III

FOOD PORTION COOKING IN UNTENDED FOOD SERVICE

All foods at 0°F.
1250 watt microwave oven
425°F. Jet Crisping

Container Code:
Microwave only - Class I
Inverted - A
Non-Inverted - B
Crisper & Microwave - Class II

PRODUCT	PORTION SIZE	CONTAINER	HEATING METHOD	HEATING TIME	QUALITY INDICATIONS
STARCH					
A. Mashed Potatoes	3 oz	Class I-B	1. Microwave 2. Steam	1½ Min.	1. Uniform heating to 185°F. 2. Fluffy, moist texture 3. No scorching or drying
B. Boiled Potatoes	3 oz	Class I-B	1. Microwave 2. Steam	1-3/4 Min.	1. Moist, yet firm texture 2. Good shape retention 3. Uniform heating to 183°F.
C. French fried Potatoes	3 oz	Class II	1. Microwave 2. Jet Crisper	1 Min.	1. Crisp exterior 2. Moist interior 3. Golden color 4. Uniform heating to 160°F.
D. Hash brown Potatoes	3 oz	Class II	1. Microwave 2. Jet Crisper	1 Min.	1. Crisp exterior 2. Moist interior 3. Golden color 4. Uniform heating to 180°F. 5. Good flavor development

PRODUCT	PORTION SIZE	CONTAINER	HEATING METHOD	HEATING TIME	QUALITY INDICATIONS
<u>MEATS</u>					
A. Hamburger	6 oz.	Class II	1.Microwave	2 Min.	1. Well browned exterior, hot pink interior 2. Tender texture 3. Good flavor development 4. Uniform heating to 145° center
B. Sliced Beef in Gravy	6 oz.	Class I-A	1.Steam 2.Microwave	2 Min.	1. Moist, tender texture 2. Appropriate flavor 3. Uniform heating to 160°F. 4. Absence of dried edges
C. Sliced Pork in Gravy	6 oz.	Class I-A	1.Steam 2.Microwave	2 Min.	1. Moist, tender texture 2. Appropriate flavor 3. Absence of dried edges 4. Uniform heating to 168°F.
D. Ham Slice	6 oz	Class I-A	1.Steam 2. Microwave	2 Min.	1. Moist, tender texture 2. Appropriate flavor 3. Absence of dried edges 4. Uniform heating to 172°F.
E. Turkey, Dressing in Gravy	6 oz.	Class I-A	1.Steam 2.Microwave	2 Min.	1. Moist,tender texture 2. Moist dressing 3. Absence of dried edges 4. Uniform heating to 185°F.

PRODUCT	PORTION SIZE	CONTAINER	HEATING METHOD	HEATING TIME	QUALITY INDICATIONS
F. Fried Chicken	6 oz.	Class II	1. Microwave 2. Jet Crisper	2 Min.	1. Crisp exterior texture 2. Moist interior texture 3. Golden color 4. Uniform heating over 160°F.
<u>VEGETABLES</u>					
A. Green Peas	3 oz.	Class I-B	1.Microwave 2.Steam	1 Min.	1. Color retention good 2. Moist but firm texture 3. Uniform heating to 200° F.
B. Green Beans	3 oz.	Class I-B	1. Microwave 2. Steam	1 Min.	1. Color retention good 2. Tender-crisp texture 3. Absence of dried spots 4. Uniform heating to 180°F.
C. Broccoli	3 oz.	Class I-B	1. Microwave 2. Steam	1 Min.	1. Color retention good 2. Tender-crisp texture 3. Absence of dried areas 4. Uniform heating to 185°F.
D. Creamed Peas and Carrots	3 oz.	Class I-A	1. Microwave 2. Steam	1 Min.	1. Absence of dried edges or separation in cream sauce 2. Moist texture 3. Good shape retention in vegetables 4. Uniform heating to 162°F.

The testing of baked and fried foods showed that recipe formulation is very important to a satisfactory use of microwave plus Jet Air impingement because of the speed of cooking involved. Thin coatings such as Tempura batter and relatively dry breadings result in products with a delicate crisp exterior. Heavier coatings need to be fried more completely before chilling because the very rapid heating reduces surface drying and especially since the application of microwave encourages moisture migration from the interior of the product.

Package development played an important part in tests for crisping and browning foods. The product required adequate moisture protection in frozen storage, yet had to be available for crisping and browning heat. Tests for the best package design covered a wide range of materials as well as confirmed that application of external heat along with microwave cooking produced a superior product. (Appendix B, Pages 145, 156.

TREATMENT OF INDIVIDUAL FOODS

As the tests involving foods progressed, it became evident that each product required a specific time, package, and heating means not necessarily the same as for other products. Furthermore, individual preferences of the consumer may dictate variations within each of these cooking requirements. An example of difference in consumer preference may be found in the case of degree of cooking of vegetables. Some consumers prefer very well cooked vegetables with no crispness while others prefer a tender crisp character. Another example is the degree of doneness in beef. Each food product under study was tested to determine the optimum treatment for that product to meet commonly accepted standards, with the expectation that recommended cooking requirements would be altered to meet the general needs and preferences of groups being served.

Some potato products such as mashed and boiled benefited from the presence of steam, while others including hash brown and French fried required surface crisping. (Appendix B page 122) The texture of mashed potatoes is foamy and tends to be self-insulating. Steam is a valuable aid in thawing. Steam also aided in heat distribution to the round particulate shape of the boiled new potatoes. Three ounces of mashed potatoes heated from frozen in a closed, vented package for 1½ minutes reached a temperature of 185°F. Canned, boiled new potatoes in a 3-ounce sample reached 183° when heated for 1-3/4 minutes. French fried potatoes heated for one minute reached a temperature of 190^{O}F., and hash brown potatoes heated for 1 minute reached 186^{O}F., with a resultant crisp exterior and golden color.

A 3-ounce portion of rice heated from frozen in a closed, vented package for 1 minute with microwave only reached a temperature of 194^{O}F. Steam generated in the package helped distribute heat evenly throughout the particles and maintain a moist, fluffy texture. (Appendix B page 112).

A chopped sirloin pattie, charbroiled, seasoned, and partially cooked was tested for making hamburgers or steaks (Table III). This product had a cool, pink center with well browned tender exterior when heated by 1 minute microwave only, plus one minute microwave and Jet Air impingement in an aluminum tray. The aluminum tray served to slow microwave cooking to avoid overheating, and to act as a conductor for the heat from the air jet to brown the bottom. Serving and eating this product showed good flavor development as well as optimum texture.

Five ounces of sliced beef with one ounce of gravy was heated to 160^{O}F. and above in two minutes with microwave only. (Appendix B, page 111). An inverted package was chosen because of overcooking the thin edges of the gravy and the tendency of liquid to fall to the bottom of the container when cooked. When the tray was inverted after heating and before serving, the liquid poured over the meat. This aided in heat distribution as well as improving aesthetics. The steam generated in the closed package during cooking helped heat distribution and preserved a moist texture.

Five ounces of sliced pork with one ounce of gravy was tested in an inverted tray, and reached an internal temperature of 168^{O}F. in two minutes. (Appendix B page 111). As in the above test, discarding the part of the box used for cooking removed unpleasant effects of slight edge drying, and inversion poured gravy over the meat just before serving. This enhanced the appearance, texture and heat uniformity of the product.

A six-ounce portion of ham slice with raisin sauce was frozen and tested in a closed package heated for two minutes by microwave only and reached a temperature of 172^{O}F. (Appendix B page 111).

One-half ounce of gravy, 1 ounce of dressing and 4½ ounces of sliced turkey were packed in that order with the gravy on the bottom to be inverted before serving and frozen. Heating this portion for two minutes with microwave resulted in a temperature of 135°F. (Appendix B page 153). Inversion had the same effects as for beef with gravy and pork with gravy. Slightly higher microwave power will be needed.

Since fried chicken is a food that requires crisping, the 6-ounce sample was packaged with a self-opening lid. Equipment available at the time of that test dictated that a 1250-watt rated output microwave oven and a powerful Jet Crisper be used in parallel. The frozen sample was heated first in the microwave, then in the Jet Crisper and reached temperatures well over 160°F. This sample possessed a highly satisfactory exterior texture. (Appendix B page 156.) A six-ounce sample heated for two minutes with only microwave reached a temperature of 198°F., but lacked crispness. (Appendix B page 122.)

Green and yellow vegetables as a class are foods that benefit from moisture retention. Therefore, these were heated in microwave only in closed vented packages (Appendix B page 111). Three-ounce samples of frozen green peas were heated for 1 minute and reached a temperature of 200°F. The steam generated in the package helped distribute heat evenly over this small, round particulate food. Frozen green beans treated similarly were heated for 1 minute and reached a temperature of 180°F. Broccoli requires longer cooking time because the cellulose in the stems requires softening. Three ounces of frozen broccoli heated for 1 minute reached 185°F. A longer period may be necessary for portions with more stem area. Frozen creamed peas and carrots reached a temperature of 162°F. when heated for 1 minute. Green and yellow vegetables in microwave heating tests, (Appendix B page 111) generally showed good color retention and tender-crisp texture. Although specific tests concerning nutritive retention were not within the scope of this study, it was thought that the speed of microwave cooking was helpful in preserving vitamin content.

3. PACKAGING:

Many packaging materials were obtained and evaluated for usefulness in storing, heating and/or serving of foods.

FOOD SERVING CONTAINERS of representative types were obtained and evaluated from aesthetic and utility aspects. These are listed in Appendix A, p. 54.

The possibilities of storing foods and then dispensing onto serving plates either before or after heating were considered because this is the food service which is generally associated with meal service in contrast to snack or vending types of food services.

China or other inorganic serving dishes, or so-called unbreakable melamine dishes are highly developed and attractive. They are readily cleaned and are widely accepted for quality meal service. They might be practical for untended food service which was associated with a dining room which has dishwashing facilities.

Aluminum meal serving containers are widely used in the general group of "TV" dinners. These containers are used mostly for retail meals or portions with one to four compartments. They are generally not very attractive for meal service, but they are quite functional for storing and heating foods. Some newer smooth surface and printed aluminum containers are appearing. Some of them require thicker metal than the wrinkled formed foil trays but progress is being made in reducing cost and increasing attractiveness. (23)

Plastic plates made by thermoforming inexpensive polystyrene, vinyl or other thin sheets are used for holiday plates and are colorful but fairly thin and flexible. None of those observed were acceptable for microwave heating though use of other materials would improve practicability for such use.

Plastic foam service plates have good insulating properties and some have excellent appearance. The type with relatively high temperature foam and high temperature film laminated over the foam (Sweetheart Corporation) withstand microwave heating and give excellent cutting surface and appearance. The particular materials in the plates are not good moisture barriers.

Cellulose or "paper plates" are available in many forms and compositions. The molded pulp trays (Keyes Fibre Co. & Diamond International, Inc.) and serving dishes are fairly rigid and reasonably attractive. Some forms denoted as ovenware withstand both microwave and oven heating temperatures (425°F., 2 minutes) reasonably well. Foods were not protected from moisture loss in the pulp-board dishes and some soaking of fat or water into the board was apparent when portions were heated in these plates. They should be limited to short time storage and use.

Formed paper plates are inexpensive and easily printed serving containers. Varying board thicknesses, coatings and laminated film coverings are available. These paper plates are too flat to be complete containers or to retain the products during shipping or handling. If overwrapped with shrink film the plates may form a part of a container for storage and heating in microwave. Some of the paper plates browned too quickly in 400° oven, but materials used in trays and boxes indicates that paper plates to withstand oven temperatures could be made if extra cost of material is warranted.

PORTION PACKAGES in the general categories of bags or pouches, trays with lids, and boxes folded from flat stock were evaluated from the viewpoints of storing the product and then dispensing onto a serving plate, either before or after heating; and also, from the viewpoint of the same container being used through storage, heating, and serving.

Bags or pouches using foil laminations are widely used for storing individual frozen food portions. These were observed and heated in both hot water and in hot air ovens of both Jet and still-air type in the course of work prior to this project. Microwave heating through a full foil-covered pouch is, of course, ineffective. In spite of using thin frozen food sections of 3/8-inch maximum thickness, heat penetration from surface heating by hot water or hot air through the portion did not bring the center to serving temperature in two minutes. Since many food portions by product shape must be more than 3/8-inch thick, the use of foil bags or pouches and surface heating was not found to be sufficiently versatile to be further pursued for this project.

Bags or pouches using laminations of Mylar and polyolefin or ionomer were microwave transparent and foods packed in them were heated quickly in microwave and were advantageous from product protection, cost, and durability viewpoints. The bag or pouch packs are used for meat and gravy, vegetables, and some starches. However, foods which need particular shapes or arrangements such as turkey slices over dressing, breaded fried chicken, or decoratively shaped portions suffer from packaging in a flexible container. It is possible that portions can be frozen and then packed in thin flexible pouches, bags or overwraps for minimum cost of packaging during storage. If the product was then dispensed onto another container for heating and serving, the flexible packages may be quite applicable for use with Untended Food Service.

Packages for storage, heating, and serving of food portions need to provide form as well as coverage. Rigid or semi-rigid trays or boxes are desirable. Many types (summarized in Appendix A) were observed and tested. The use of flexible pouches or wrapping over trays can be used to give moisture protection during storage and heating. For easily handled products such as breads, pastry desserts, or roll type snack foods, a thin heat-resistant pouch inside of a rigid bag is functional.

For locations where the Untended Food Service may be used in conjunction with a nearby kitchen for short time storage of refrigerated or frozen portions, the trays of molded wood pulp with water and grease repellant coatings were functional. Tests were run with thin heatseal polyester (Three M Company) applicator covers. Rigid lids are needed to be adhesive bonded to the tray for use in stacks. Lids with openings covered with heat shrinking film were applied for packaging products such as fried chicken and French fried potatoes which require oven crisping and browning. These pulp trays do not provide moisture protection for the product nor are they moisture stable enough to resist softening in long storage. There is some staining of the trays by water and fat during cooking. The trays soften during heating from steam and moisture if the surface is not dried by the oven. Cellulose pulp trays or serving dishes may be convenient to fill, reasonably attractive in design and serviceable in short hold situations. They are not suitable in present forms for long term storage.

Folded or formed trays or boxes made from sheets or roll boxboard are potentially inexpensive and some forms can be made on existing high speed equipment. Folded and glued trays made from repellant coated boxboard are inexpensive and may be used for short storage applications somewhat as the pulp trays are used.

Laminations of plastic coatings to the board before or after forming offer many variations in which the board lends mechanical strength and the laminated film offers sealed surface and finish.

Paper board with polyethylene coating on both sides as produced for milk cartons gives fairly good moisture protection, mechanical strength and low cost. Special food portion trays (International Paper Company) from such stock are being used commercially for microwave heating of food portions. The trays have thermoplastic corner seals to be leakproof and are fitted with pressure sensitive or heat sealing lids of the same material. These polyethylene coated board materials withstand microwave heating quite well but do not withstand oven crisper temperatures in 300^{o}F. range without loss of corner seals and other problems. Higher oven temperatures can be tolerated depending upon dwell time and heat transfer rates.

Paperboard trays coated with polypropylene withstand oven temperatures up to about 350^{o}F. in most food portion heating. Three special types of trays have been developed and are being marketed in Sweden. The Sprinter (Appendix B, page 151) tray has a double folded 45^{o} diagonal corner which is crushed to make a diagonal lip around the corner. The lip is heat-sealed to give structure and a fairly flat sealing surface. The cover can be a heat-sealed flat portion of the same stock. This lid is difficult to remove from a hot product. The A & R Stalox-Modul (19) has single or multiple folded corners and the crushed and heat-sealed lip for cover attachment. These forms of coated board are not presently available in the U. S. but are used for food portions and retail dairy products in Europe. The single folded corner construction as exemplified in the Stalox-Modul can be produced on box equipment in the U.S.

A special board and plastic liner tray called Tritello by A & R (19) combines a printed and die-cut board blank with a thermoformed plastic liner. The liner covers the tray lip so that a snap-on or a heat sealed lid may be applied. This package requires quite special equipment for manufacture and is more expensive than trays formed from coated flat board but it gives rounded corners and latitude for attractive shapes and printing. It permits use of thinner liners than in monolithic plastic thermoformed or molded products. The thinner liners may make practical the application of relatively expensive high temperature plastics to provide containers suitable for both microwave and Jet Oven heating.

Plastic containers thermoformed from styrene (Appendix A-1) vinyl-like (probably nitrite-acrylic polymer) linear polyethylene (Aladdin Plastics, Inc, Subsidiary of Lennox Plastics P. O. Box 92796 World Way Postal Center, Los Angeles 90009) and polysulfone (Appendix A-1) can be protective and reasonably attractive. The high temperature vinyl-like trays and the polysulfone were fairly satisfactory for microwave heating of foods. The linear polyethylene trays give good moisture protection, and mechanical durability at reasonable cost but are subject to penetration by localized spot heating of oils or sugar solutions. The polysulfone trays have been expensive, but progress is being made in using 10-or 12-mil stock instead of 18-mil to reduce cost per package. The 12-mil trays in 6¼ x 1¼ x 5 inch dimensions are quoted (Form Plastics Company, 2720 Greenleaf Avenue, Elk Grove Village, Illinois) at \$50.00 to \$70.00 per 1000 in quantities of over 50,000 trays without covers. These trays have limiting rigidity for stacking. The polysulfone trays are suitable for microwave and moderate crisping temperatures up to about 375°F. Rapid browning temperatures of over 400°F. cause severe distortion.

Plastic containers molded from melamine (Appendix A-1) and highly filled high temperature polymer (Appendix A-1) give excellent rigidity, neat appearance, and hard cutting surface. Lids can be heat-sealed to the trays, or box-like or sleeve covers applied to permit stacking in shipping and portion storage. The melamine trays are apparently acceptable for heating at 425°F. for short term crisping and browning as well as microwave heating. The alkyd or filled polyester trays give apparent and objectionable odor at about 400°F. and higher temperatures.

Tests of melamine trays with board lids which included perforations covered with heat shrinkable moisture-proof film (Appendix B page 158)protected the fried chicken portions well during storage, opened quickly, and heated effectively to crisp and finish browning of the chicken at time of serving. Use of nylon netting with the Saran film prevented sagging of the film onto the chicken when the film melted in opening the package.

The reuse or disposability of each of the packaging materials was considered and is coded in the summary of packaging materials in Appendix A-1.

POSSIBILITIES IN NEW PACKAGING:

The tests and evaluations of many plastic materials, metals and board compositions and package design show possibilities of new packages which give workable answers for various foods and heating methods. There is need for higher temperature plastic materials at reasonable prices to be used as monolithic trays or as coatings and linings to produce containers which are stable in crisping and browning temperatures. The emphasis on mechanical and electrical plastics is fostering development and commercialization of many new high temperature plastic developments. These are listed in bibliography references and in Appendix A-1.

Some possibilities of new plastics for package use (though not necessarily FDA approved at present) are among the myriad of new engineering type plastics. (30,37,38,39,40).

Some of these are:

Amoco Chemicals Company "Torlon" - Polyamide-polyimide blends are reported to have service temperatures of 550°F. The imide addition adds high temperature tolerance to the nylon family.

E. I. du Pont Company - Teflon family of fluorinated compounds. PFA with perfluorinated alkyl side chains offers strength stiffness and dimensional stability at temperatures up to 500°F.

Du Pont Tefzel ETFE polyfluoro carbons have improved mechanical strength over older teflons and have continuous rating of 300°F. (150°C.) and intermittent temperature tolerance of 392°F. (200°C.). Coating materials of various teflon materials are applied to metals for cooking and surface protection value. Application as container coatings depends upon economics as do all the relatively expensive fluorine containing plastics.

Many new suppliers and variations of halogen-organic polymers are in production. (37)

E. I. du Pont Company "Kapton" solvent cast polyimide film is expensive but it shows temperature stability up to 800°F. Very thin films, which are quite strong, may have practical use in packaging.

Thermoplastic polyesters which are developed for high temperature injection molded mechanical parts by Celanese, Eastman and General Electric Company offer promise of additional films and for molded containers. Three-M Company has marketed oven bake polyester films and heat-sealing polyester films which demonstrate strength and temperature tolerance for possible liners, covers or laminations to give high temperature semi-rigid or rigid portion packages.

Air Products Sta-Flow vinyl copolymer is applied in toys but offers higher temperature stability than other vinyls. This is not oven temperature material but may make tough durable containers for microwave heating.

Polyether sulfone announced by Imperial Chemical Industries (I.C.I.) in 1972 (36) offers about 30^{o}F. higher softening point than the Union Carbide polysulfone product presently finding its place in thermoplastic formed load portion trays. This extra temperature is important in the range of oven temperatures required for optimum and rapid food finishing.

Poly 4-Methylpentene (40) TPX by trade name, developed by I.C.I. and licensed to Mitsui Petrochemical in 1973 has crystalline melting point of 464^{o}F. It is tough, has good appearance and is expected to become a major factor in food portion packaging both as monolithic material and as melt coated on paperboard.

Composite packaging materials such as now used for flexible portion packs in bags or pouches are also thermo-formed to make rigid and semi-rigid trays with lids. (30)

Composites such as polyethylene and nylon (St. Regis) give excellent product protection in vapor retention and are thermoformable to give high temperature composite coatings for paperboard.

The use of thin high temperature film bag inside a supporting box may prove to be very practical though less easily opened and less aesthetically pleasing than rigid trays. A variation is the loose bag made of inexpensive 3/4-mil "layered 100% polyester with heat-sealable face" supplied by Three-M Company to Sara Lee Company for heat-in-oven dinner rolls.

For rigid and semi-rigid containers new technologies and new materials in plastic foams offer promise. New foam techniques (33,34) offer promise of high temperature molded and thermoformed trays and containers with outstanding appearance and properties. The broad line of relatively high temperature structural foam forms offered by General Electric

Company for mechanical uses indicate the possibilities of incorporating dense skins with low density interiors to give surface hardness with stiffness from minimum weight material. Recently developed foaming equipment and compositions of high temperature (33) materials make this quite promising for portion packaging.

The high temperature styrene foam with high temperature styrene laminant used to make "Silent Service" dinnerware (Sweetheart Cup Company, Ownings Mills, Maryland) should be adaptable to particularly attractive practical containers for foods for heating in microwave.

In the packaging industry there is tendency to think of materials which withstand boiling water as high temperature plastics. New plastic chemistry offers many new materials in the 250 to 400°F. use range. (31, 32, 43). Some of these new materials have good promise for bake-in packages.

Further, high heat resistant resins (35, 37, 43) lists several research materials which have thermal stability in 200 to 600°C. (392 to 1112°F.) temperature range.

Ceramic and glass packaging materials should not be overlooked in view of new stronger, thinner and lighter containers, crack resistant coatings, and regrindable recycling possibilities. New cleaning developments may make reusable containers desirable in some applications for both aesthetic and waste control aspects.

4. EQUIPMENT TESTING:

After workable heating means and packages were identified, choice of mechanical equipment and system concepts could be evaluated. There are so many possibilities, for freezer or refrigerator design, storage, and retrieval systems, selection and control variations that it seems unnecessary to record most of the alternatives which were considered and by-passed in selecting a system with a workable combination of equipment components.

Consideration of calculated heat requirements, heating and combining sequences as bases for design concepts are shown in Appendix B-3. Energy requirements for heating a complete meal in less than two minutes does not give sufficient energy from the 1250-watt microwave units generally available.

Patent searches at the (Page 53-E) U.S. Patent Office offer many details of food storage and vending and of resistance, microwave, induction and other heating means.

The contractor's personnel had assisted in designing a prototype (Appendix C-2) and then had designed and built an automatic meal serving unit (page 176). This test unit stored a variety of food portions in frozen or refrigerated packages, then retrieved the portions selected, assembled them into a meal entity of up to three portions, heated the meal in a microwave oven and then presented the hot meal. The engineered model which incorporated cylindrical turrets with portions stored on steps of a "Descending Staircase" design incorporated many engineering details for reliability and ease of production. (Appendix C-3, page 177)

The first unit of the engineered automatic meal serving unit was loaned to this contractor for testing on this project. The unit was actually a third generation development if one considers available vending machines, the prototype of Murray, and then this unit engineered for Mr. Murray. Some items which this model emphasized as needing change for the Untended Meal Service specification of this project were:

1. Proper heating of each of the several portions of different foods in one meal.

2. Heat programming if only one or two portions were selected instead of three.

3. Variation in heating if one or more heat-shielded portions were substituted for normally heated portions in full meal heating.

4. Flexibility in size and shape of portion packages to be handled in the unit.

5. Requirement to crisp and brown some products.

6. For frozen foods, surfaces of the dispenser from the freezer and discharge interfaces at the bottom may be vulnerable to ice problems.

7. The turret design required placement of individual portions when loading, which is slow.

8. The round turret design requires considerable unusable space in the freezer, particularly if large numbers of portions are stored.

9. Storage and gravity feed downward to the collecting belt wastes storage space below the belt which is at convenient serving height.

A stack and lift design for storing stacks of food portions, lifting one portion above the front line at time of selection, and then dropping the stack fully below the frost line in the freezer for further storage was made and tested. A frame for a stack of portions was constructed with a movable chain at one side and rigid guide near the chain. Removable shelves which latched into the chain and the guides were made. The guides were placed low enough on the chain to receive a stack of portions from the shipping carton while keeping the top portion below the top of the freezer. When a portion was selected, the chain was driven to lift the whole stack to a position so that one portion was pushed above the frostline and could be swept, along with other selected portions, to the heating area.

For loading additional portions a second shelf was inserted below the first stack and the new product was placed on the second shelf. Then the first shelf was removed allowing the remainder of portions from the previous loading to rest on top of the new loading. Thus the first-in portions are first-out to avoid any one package staying at the bottom for excessive time.

A single stack and lift column was made and loaded with commercially frozen vegetables in wax paper wrapped cartons. The cartons were exposed to collect water condensate and then the assembly was placed in a $0^{o}F$. blast freezer.

Packages elevated well. There was some sticking between portions but they wiped off without crushing the carton.

Parallel with this project, and at the contractor's own expense, a half-size model of an automatic meal server incorporating features needed for this project was built to study use logistics and mechanical aspects of Untended Food Service. This model is defined in the drawing in Appendix C-3, page 177.

The model was taken to U. S. Army Natick Laboratories and reviewed with the project officer and presented at the R & D Associates meeting on October 18, 1973. General system and design concepts were evaluated and found to be practical in general. Many smaller design factors require expert engineering to make a reliable practical unit.

The general design and certain mechanical features were reviewed by a consulting mechanical engineer who has extensive experience in food freezing and heating and problems of freezer mechanisms. He found the general concept workable and most of his suggestions are included in the system recommended.

The general concepts were reviewed with a human engineering consultant with unusual experience as test pilot, instrument panel engineer and in food acceptance. His comments, in general were pointed toward logistics of display and use, but are noteworthy in making the unit accepted and appealing in certain types of locations.

V. DESCRIPTION OF A FEASIBLE SYSTEM: (General Concepts, Foods and Packaging, and Equipment)

To present one workable system with references to some of the many alternatives is the result of these evaluations, tests, observations and developments. The recommendations are presented for a frozen storage unit which meets more severe requirements than that for storage of refrigerated foods and can be used for either frozen or refrigerated storage.

The general concepts of such a system are shown in general layout in Appendix C-4. This design concept combines the following mechanical and electrical components:

1. A tall freezer with side door for loading and fitted with top discharge for the collator-retriever. The portions are stored in closely packed vertical stacks within separate guides called stack-lifts (No. 4, page 175). A removable shelf is inserted at desired height in each stack-lift and the portions are placed on top of it. For additional loading a second shelf is inserted at proper height below the first stack. Then the new portions are loaded, the first shelf removed and the older portions dropped onto the top of the new portions so first-in first-out delivery is maintained. The stacks for each row of portions, for example, the four stacks of meat entrees are combined into one panel which rolls out the loading door for convenient and rapid loading. A flexible curtain covering the door and the loading area can be employed to reduce moisture collection on packages or equipment if the unit is installed in outdoor or severe humidity locations. The tall freezer is recommended to permit maximum storage space in minimum volume. The tall lift-stacks may require particularly strong containers in some cases. However, multiple shelves in each stack-lift can be used to store smaller stacks and the removable shelf under the top stack will need to be removed when the control signals "Empty". This system is recommended to give maximum storage capacity and minimum working parts in the freezer.

2. The collator-retriever (No. 5) sweeps across the top of the stack-lifts to collect the portions selected. The top of each stack-lift is covered by a hinged or flexible partial cover which allows the selected portion to be swept out of its stack-lift and to be carried over the succeeding stack-lifts. The collator-retriever carries the selected portions to the elevator (No. 6) which lowers the portions onto the three separate heating conveyors. (No. 7)

3. The heating conveyors (No. 7) carry each individual portion into a separate heating compartment. This heating compartment is fitted with both microwave (2450 MHz) and Jet-Air (Appendix C-1, page 175) surface heating. It may also be equipped with masking or shielding inserts which can be tailored to special heating requirements. The ovens need to have some venting of food vapors. The heating conveyor should move the food product in reciprocating action relative to the oven to assist uniform microwave and Jet-Air heating.

   The heating conveyor also delivers the food to the serving area. The mechanics and the heating cycles are designed so that all portions are delivered at the same time.

4. The serving section is fitted to support at least one edge of a tray and to permit sliding the hot portions onto proper positions on the tray. It is recommended that the foods remain covered until just before eating instead of removing covers while picking up drinks or paying a cashier. This system can prepare foods to their optimum condition and this condition should be preserved until ready to eat. Opening the portions after sitting down to eat can be a very valuable appreciation value of this system in contrast to long cafeteria type lines or to other food service systems in which the hot portions get cold while waiting in line or while eating salads or other foods.

General specifications for the equipment recommend that each of the stack-lift sections and the oven sections be made like the others for uniformity, for versatility, and for production practicability. A different retainer door or location on the stack-lifts is about the only change needed to accommodate wider or narrower packages. The stack-lift design and the conveyor and elevator concepts are designed to handle a wide variety of package sizes.

Package sizes for different portions which were found acceptable were:

PORTION	MINIMUM	MAXIMUM
6-ounce entree	5 x 7/8 x 4¼ inches	7½ x 1¼ x 5 inches
3-ounce vegetable or starch	3½ x 7/8 x 4¼ inches	4 x 1¼ x 5 inches

Package size is important to the appearance and to the proper heating of the food. Too thin or too thick sections may present heating difficulties.

Package constructions of many forms can be used. Some of these are diagrammed in Appendix A-2, page 61.

The packages for foods requiring microwave heating only are designated Class I in Appendix A-1. The materials for these packages, as reviewed in tests and observations, Section IV, may be selected from many types as long as the package gives rigidity, reasonable moisture protection, temperature tolerance of 180 to 212°F. and is readily disposable. For some foods such as "chili" or sugar syrups, monolithic plastic trays may be perforated by local spots of oils or sugar which exceed boiling water temperatures so applications must be selective.

Polyolefin coated boxboard and polysulfone, nylon, or melamine trays with boxlike or adhesive bonded covers were found to be satisfactory for microwave only (designated Class I in Appendix A-1) heating.

Similar packaging materials were found to be suitable for the portions which needed to be inverted for serving because these are generally those foods with gravies or sauces. The general forms and filling and serving positions are shown in Appendix A-2 page 61.

Fried, baked or browned foods which need crisping and browning may require that the Jet-Air in the ovens be applied during heating. The packages for such foods as steaks, fried chicken, and French-fried potatoes need to withstand at least 425°F. to accomplish surface finishing within less than two minutes of heating from frozen.

Packages for these crisped or browned products, designated Class II in Appendix A-1, must be made of high temperature tolerant materials and be designed to be self-opening when the hot air jets are applied. Boxes made of low resin cellulose board coated with polyester film were found to be satisfactory if combined with lids which had openings covered with heat shrink polyvinylidene chloride film (Saran). Such construction is shown in Appendix A-2 page 63. The film should be bonded to the top of the box between holes to prevent segments adhering to food when the film shrinks apart. A good construction added an open mesh nylon net under the shrink film to retain the shrunken film and to permit air jet crisping or browning action.

An alternate pack for this use was the melamine thermoset plastic tray with the vinylidene wrapped over the top and sealed by cling of the film. A lid consisting of half of a low resin paper board box to aid stacking is needed. The self-opening film mounted to the boxboard cover is better for large production but the cling wrap film cover on the trays is useful for adjacent kitchen or laboratory packaging.

Polysulfone formed trays will be satisfactory for some products in oven baking if the heat resistant cover shields the lips and edges and if the food covers and cools the full bottom of the tray. Aluminum portion trays with crimped-on-lids of paperboard covered with polyolefin or polyester may be quite satisfactory for microwave heating of some foods such as green peas where steam inside the package aids energy distribution.

Aluminum trays should be relatively shallow with depth not over one-fourth of minimum horizontal dimension. Heating times in aluminum will generally differ from microwave heating in neutral materials.

Aluminum trays with crimped-on-lids of foil-coated paperboard with windows of polyester function well for combination microwave and Jet Crisper heating of ground beef patties in sauce because the aluminum reduces edge heating, the Crisper heats the bottom of the tray to melt sauce and the microwave concentrates on the thick section of the meat pattie. Other foods with thick center sections and thin outer edges are favorably heated in this manner.

Aluminum trays with crimped or formed paperboard covers are particularly good for products requiring crisping and browning if the self-opening covers or lids are used.

As in paperboard containers, the aluminum trays may be of many forms and they must be suited to product and consumer requirements for economy, appearance and disposability.

The oven sections should be made equivalent for versatility and practical manufacture and servicing. For maximum package width of eight inches, each oven and conveyor should be designed for approximately ten inch clear width. For maximum package length of five and one-half inches the oven should be approximately ten inches clear inside length so that the portion can move forward and back to distribute microwave and jet air heating.

Power input by microwave to each section should be from a discrete power unit. Commercial microwave ovens with 1250 watts output and cavity coupling favorable to the small single portion loads give more power than needed for three-ounce portions but are indicated to handle six-ounce entree portions. It is recommended that the same power unit be used for all three ovens so that components are interchangeable, so that food portions can be shifted from one to another location in the system in case of failure of any section of the oven.

It is recommended that the Jet Air section be constructed with a single well-insulated heater unit which is maintained at about 425°F. with sufficient heat capacity to crisp or brown in all three ovens on demand. The Jet Air for each oven section should be separately controlled and timed along with the microwave heating by the individual selector button. Provision for keeping the ovens dry and for venting vapors must be included in the air circulation system.

The display and control section of the Untended Food Server should describe the food available in each of the categories. Preferably, the foods and selector buttons should be arranged to encourage a balanced meal of meat, vegetables, and starches.

The selector buttons should select the particular portion and the proper program for heating that portion. The timing for heating each portion should permit wide flexibility in timing of microwave and jet air heating. The timing for microwave heating should include pulsing to permit spaced and repetitive heating periods. Further, each selector button and timer combination should be easily adjustable to proper heating of the food portion which is placed in the corresponding stack-lift section.

The controls should progress after the selections have been made and release the selector buttons so that the next "order" can be ready for heating as soon as the first is completed.

The heating and handling timing should be arranged to deliver all heated, or cold, items at the same time. This requirement indicates that the unit operating cycle should be set for two minutes and whatever portion of that heating time is needed should be programmed to give optimum product condition. Slightly shorter time could be obtained for refrigerated foods in place of the frozen, but shorter times make proper heating much more difficult to control within product and equipment variables.

The height of the dispensing conveyor and serving shelf should be between 36 and 44 inches from the floor for stand up service and to leave room over the serving area for displays, selection buttons, and controls. The higher dispensing shelf should be used only to obtain more storage capacity in smaller storage units which can then avoid need for the elevator.

VI. A. CONCLUSIONS:

The objectives of this project have been accomplished as follows:

1. A general design of an Untended Hot and Cold Food Dispensing Unit for missile site and off-hour food service has been presented Reference Appendix C-4. This unit is the result of studies of product geometry and composition, packaging and container materials, product heating, transport technique and actuation and control methods presented in Section V Description of a Feasible System.

2. Appraisal of available heating means, Section IIIA, page 2, and tests of heating portions separately and complete twelve-ounce meals Sections IV A-1 and A-2, page 11, lead to recommendation that individual portions be heated separately. This results in more practical packaging, heating control, and tolerance in preparing high quality meals.

   Available commercial microwave ovens rated at 1250 watts output power were not quite adequate to heat all types of frozen twelve-ounce meals to serving temperatures in less than two minutes even when proper packaging helped retain steam. These standard ovens did heat six-ounce and three-ounce portions within the two-minute time cycle, Section A-2.

3. a. Container materials were evaluated for compatability with heating techniques in Class I, microwave only and Class II, microwave plus 425°F. Jet Air heating. These are discussed in Description of A Feasible System, Section V, and itemized with designations of heating technique, disposability and aesthetic acceptability in Appendix A-1.

Immediately useful container materials are described in Section V and some new high temperature materials and package manufacturing techniques are presented in tests and evaluation on page 35.

b. Heating studies of the food portions specified in several different recipes were carried out in representative portion packages.

Studies of techniques to permit simultaneous heating of a mix of meat, starch, and vegetable items in their individual containers are reported in section IV B-2. Shielding of the complete meal to control rates of heating, shielding of individual portions and the effect upon rate of power input into the oven when selected portions are shielded was studied. The recommendations of separate heating for each portion was reinforced by consideration of the fact that individual package shielding was expensive and limiting; by the many combinations of shielding required for meals assembled from a variety of portions as specified; and by the observation that shielding one portion appreciably changes the energy input to the remaining portions which makes proper heating control more complicated.

Capability of the heating system recommended to heat the meats, vegetables, and starches listed from frozen to serving temperature was simulated in tests described in Appendix B.

c. The general concepts of a mechanism in accord with the parameters determined in this study are described in Section IV-B-4, page 38.

d. To serve frozen or cold portions, the design concepts and controls in Section V-3 provide for dispensing a portion with no microwave and very little surface heating or with only sufficient microwave heating to warm the portion to the degree desired.

   The packages and the equipment design concepts permit thawing only or thawing plus warming and toasting of bread and pastry products.

e. Gravity feed techniques were considered along with mechanical and the recommended concept employs advantages of both. The stack-lift mechanism has the mechanical compactness and much of the simplicity of a gravity system combined with the advantage of forcefully lifting the portions out of the top of freezer to maintain the cold well for storage. This design eliminates individual portion loading. Elimination of individual portion holders also makes storage more compact and increases capacity.

f. Maximum use of storage space is possible in the design presented because the space below partially empty stack-lifts can be utilized, and the roll-out panels of each section in the cold storage cabinet permit access to all freezer floor spaces to store portions. Large cartons storage would require a larger freezer because the volume of the proposed unit is so fully employed.

g. The design recommended does not define details sufficiently to define compliance with requirements of appropriate agencies, but components and materials must be selected and applied in accord with requirements of National Sanitation Foundation, Underwriters Laboratories, and other agencies. The general design concepts are amenable to tight door closures, ease of cleaning, and general sanitation and safety. The food is stored in the cold section until each portion is selected and automatically dispensed. The vapors from the food are vented from a hot air oven which is self-sterilizing and drying with heat, and the foods are contained in their original containers until served.

4. The general concept of system and equipment design is very flexible. Larger storage, more choices of foods, more heating ovens or addition of cold vending without heating can all be accomplished within multiples of the components in the storage retrieval, heating, and dispensing elements.

The unit shown in the general concept design, Appendix C-4, illustrates a model with four stack-lifts in each of three tiers and equivalent displays and selector buttons. The tall stack-lifts with the elevator to deliver the portions to serving height provide space for up to fifty portions 1¼ inches thick in each stack lift. Thus this particular configuration can store up to fifty portions of each of twelve different foods or a total of six hundred portions or two hundred of the three-portion meals.

Clarification of paragraph 4, page 23 of the contract by the contract officer refers to original concepts at time of writing the solicitation and the contract when storage of complete meal units of up to twelve ounces and up to three portions was considered. Thus the above general concept drawing illustrates the largest of the specified system sizes.

The design of the 100- and 50-meal units is identical if the same number of choices is desired excepting that the elevator is not needed because the stack-lifts for cold storage are shorter. The configuration of these smaller units is illustrated by the design of the model shown in Appendix C-3.

Power requirements of the 200-meal size unit are representative of the three sizes except that a slightly smaller refrigerator compressor and one less drive motor will be used in the 100- and 50-meal sizes.

Electrical power requirements indicate that 230 volt, 3-phase 60-Hz current with 110-volt capability is desirable. Appropriate compensations can be made for most other power supplies which can furnish the amount of energy required.

The electrical load is:

Microwave heaters	3 @ 2500	= 7500 watts
Jet-Air heaters	3 @ 1650	= 4950 watts
Blowers - ¼ HP	2 @ 400	= 800 watts
Actuator motors 1/6 HP (not simultaneous use)	16@ 200 x ½	= 1600 watts
Freezer compressor ½ HP	1 @ 800	= 800 watts
Lifts, heaters and controls		= 1200 watts
MAXIMUM PEAK LOADS		=16,850 watts

STANDBY POWER, compressor lights and heaters

MAXIMUM PEAK LOADS = 8350 watts

Average power consumption, approx. - 800 watts/hour

VI. B. RECOMMENDATIONS:

1. An Untended Food Server Unit should be built and evaluated for missile site and off-hour food service.

2. Foods should be packed in appropriate packages, frozen and then heated to optimum serving condition in the Food Server to demonstrate the capability of providing high quality meals with low labor cost.

3. The logistic, economic, and aesthetic values of high quality meals being available on demand for feeding small groups should be demonstrated and evaluated to determine proper locations for such food server units.

4. Systems for applying the freedom of choice, the low labor requirements, near zero food waste, disposable containers, and other advantages of this system to mass feeding should be encouraged. This is needed to stimulate private industry interest in food and packaging for the off-hour feeding, too.

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3,619,214 Cohen, (assigned to Battele Corp.), Package With Electrodes for Heating.

3,615,713 Stevenson , (assigned to Teckton), Selective Cooking Apparatus Applying Shielding in Microwave.

3,573,923 Meiser, Dielectric Heating in Amino-plastic (Melamine) Tray by Dielectric Energy.

3,573,430 Eisler, Dispensing Means with Package Heated by Conductivity.

3,500,742 Tangay, Coded Packages (Indentation) to Control Cooking.

3,547,661 Stevenson, (assigned to Teckton) Selective Heating in Microwave.

3,469,998 Lane, (assigned to Redi Bacon Inc.) Package for Heating Bacon in Toaster.

3,394.007 Campbell, Thawing and Cooking Food in a Package Using Electrostatic Phase Shifting for Thawing and Induction Mode for Serving. Wrapper is Resonant to Generate High Voltage.

3,353,968 Krajewski, Food Package with Two Strips of Conductive Material to Influence Distribution of Microwave Energy.

3,302,632 Fichtner, Microwave Cooking Utensils with Compartments of Different Materials to Control Heating.

3,283,113 Smith, Electronic Oven for Vending Machines.

3,271,169 Baker, Compartmented Food Package for Microwave Heating.

3,240,610 Cease, Food Package and Method of Serving, (inverted to serve).

3,117,511 Everitt, Hot Dog Dispensing Machine with Resistance Heating; and Package.

3,079,913 Nelson, Compartmented Container with Varying Coatings Applied to Lid to Control Rates of Heating.

3,079,912 Breim, Compartmented Container Arranged to Heat Foods in different Compatments at Different Rates.

2,950,024 Adler, Machine for Dispensing Hot Foods.

2,714,070 Spencer, (assigned to Raytheon) Microwave Heating Apparatus and Food Package for Selective Heating by Shielding.

2,501,400 Marshall, (assigned to Raytheon) Packaged Foods Frozen and Reheated in Microwave.

2,495,435 Welsh, (assigned to Raytheon) Method of Treating Food, Packaging, and Reheating in Microwave.

APPENDIX A. PACKAGING

VII APPENDIX A. 1. DESCRIPTION OF CONSIDERED PACKAGING MATERIALS

APPLICATION CODE

CLASS I - Suitable for microwave only

CLASS II - Suitable for microwave and Jet Air impingement (425^{o}F.)

DISPOSABILITY CODE

1 - Reusable with washing
2 - Disposable by incineration
3 - Disposable by recycling

NAME - TYPE	PROPERTIES OF SPECIAL INTEREST	AVAILABLE FORMS	MANUFACTURER	APPLICATION CODE	DISPOS-ABILIT
I. GLASS AND GLASS CERAMICS					
A. Heat Resistant Glass 1. Pyrex 2. Fire King	1. Microwave transparent 2. Heat resistant 3. Chemical resistant 4. Attractive 5. Moisture resistant 6. Rigid	1. bowls 2. cups 3. baking dish 4. airline entree dish 5. tableware	1. Corning Glass Works Corning, NY 2. Anchor-Hocking Co. Lancaster, Ohio	Class II	1
B. Pyroceram Corning-ware Glass-Ceramic	1. Microwave transparent 2. Heat resistant 3. Chemical resistant 4. Attractive 5. Moisture resistant 6. Rigid	1. tableware 2. cooking vessels	1. Corning Glass Works Corning, NY	Class II	1
C. Centura cooking Vessels Glass-Ceramic	1. Microwave transparent 2. Heat resistant 3. Chemical resistant 4. Attractive 5. Rigid 6. Good moisture barrier	1. saucepans 2. skillets 3. platters	1. Corning Glass Works Corning, NY	Class II	1

D. Centura Tableware Glass-Ceramic		Not recommended for microwave	1. tableware	1. Corning Glass Works		
II. METAL						
Foil food Containers with microwave trans-parent lids	Alumi-num Foil	1. Microwave reflective 2. Rigid; semi-rigid 3. Moisture resistant 4. Heat resistant 5. Special coating needed for chemical resistance	1. Formed food trays 2. baking dishes	1. Reynolds Metals Co, Richmond, Va. 2. Aluminum Co. of America Pittsburg, Pa. 3. Mirro Aluminum Co - Manitowac, Wisconsin 4. Ekco Prodcts Wheeling, W.Va. 5. Aluminum Foil Packaging Ft.Madison, Iowa	Class II	3
III. PAPERBOARD AND WOOD PULP						
A. Chinet	Heat resist-ant molded pulp board	1. Microwave transparent 2. Heat resistant 3. Moisture resistant 4. Rigid 5. Low cost 6. Attractive	1. food portion trays	1. Keyes Fibre Company 160 Summit, Montvale, NJ	Class II (Short time storage)	2 3
B. Coated Board Trays (Meal-Eze, etc)	P. E. coated box-board	1. Microwave transparent 2. moisture resistant 3. Attractive 4. Low cost 5. Rigid	1. food portion trays	1. International Paper Co. Tuxedo Park New York	Class I	2 3

C. Diamond Deluxe	Molded Pulp-board	1. Microwave transparent 2. Rigid 3. Low cost	1. tableware	1. Diamond Int., Fibre Products Division 733 Third Ave. New York, NY	Class I (Short term storage)	2, 3
D. Dixie	Formed paper plates (coated)	1. Microwave transparent 2. Attractive 3. Low cost 4. Rigid	1. tableware	1. American Can Co., Greenwich, Conn. 06830	Class I (Short term storage)	2, 3
E. Tray-Tite	Polypro-pylene coated box-board	1. Microwave transparent 2. Some heat resistance 3. Moisture resistant 4. Attractive 5. Rigid 6. Low cost	1. food portion trays	1. Finn Ind. 875 N. Michigan Chicago, Ill. 60611	Class I	2, 3
F. Tri-tello	Thermo-formed liner in die-cut formed boxboard	1. Microwave transparent 2. Moisture resistant 3. Use of plastic film 4. Rigid 5. Low cost 6. Attractive	1. food portion trays	1. Akerlund-Rausing Box S221 01 Lund 1 Sweden	Class I	2, 3
G. StaLox	Polyole-fin coated boxboard	1. Microwave transparent 2. Moisture resistant 3. Semi-rigid 4. Low cost 5. Attractive	1. food portion trays	1. Akerlund-Rausing Box S221 01 Lund 1 Sweden	Class I	2, 3

IV. PLASTICS

A. Aristo-crat	High Impact polysty-rene	1. Microwave transparent 2. Rigid 3. Low cost 4. Attractive 5. Low heat resistance	1. Tableware	1. Polytherm Plastics, Republic Plaza Middletown, NY 10940	Class I	2
B. Celanex	Thermo-plastic polyester	1. Microwave transparent 2. Moisture resistant 3. Heat resistant 4. May be extruded 5. Semi-rigid	1. Resins 2. Sheets	1. Celanese Plastics Co. 550 Broad St Newark, NJ 07102	Class II	2
C. Every-ware	Foamed poly-styrene	1. Distorts in microwave 2. Thermal insulating 3. Attractive 4. Low cost 5. Rigid	1. Tableware	1. Polytherm Plastics, Republic Plaza Middletown, NY 10940	Not suitable	
D. Gourmet-ware	Foamed styrene with film laminant	1. Microwave transparent 2. Moisture resistant 3. Insulating 4. Attractive appearance 5. Low cost	1. Trays	1. W.R.Grace Co. Formed Plas-tics Division. Reading, Pa. 19603	Class I	2
E. Halor	E C T F Fluor-polymer	1. Heat resistant 2. Chemical resistant 3. Moisture resistant 4. Microwave transparent	1. Resins 2. Films 3. Fibers	1. Allied Chem. Co - Box 2365R Morristown, NJ 07960	--	2
F. Kymar	Fiber with polyvi-nylidene fluoride	1. Heat resistant 2. Chemical resistant 3. Microwave transparent 4. Rigid	--	1. Pennwalt Corp Plastics Dept 3 Parkway Philadelphia, Pa 19102	Class II	2

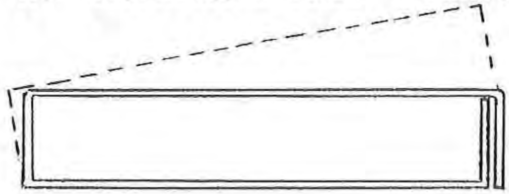
G. Lexan	Polycarbonate	1. Microwave transparent 2. Heat resistant 3. Chemical resistant 4. Rigid 5. May be thermoformed 6. Moisture resistant	1. Resins 2. Sheets 3. Films	1. General Electric Plastics 1 Plastics Ave Pittsfield, Mass. 01201	Class I Class II (?)	2
H. M-16	H D P E laminated to LD polyester	1. Microwave transparent 2. Heat sealable 3. May be thermoformed 4. Non-rigid 5. Chemical resistant 6. Moisture resistant	1. Films	1. Packaging Products 1101 Guincotte Kansas City, Mo.	Class I	2
I. Nomex	Nylon	1. Microwave transparent 2. Heat resistant 3. Chemical resistant 4. Moisture resistant 5. Blistered in oven temperatures	1. Staple 2. Fibers 3. Fabrics 4. Paper	1. E.I.duPont Nomex Mktg. 1157 Centre Rd Wilmington, Del 19898	Class II (?)	2
J. Noryl		1. Microwave transparent 2. Moisture resistant 3. Chemical resistant 4. Rigid 5. Attractive	1. Resins	1. General Electric Plastics 1 Plastics Ave Pittsfield, Mass. 01201	Class II (?)	2
K. Plassware	Thermosetting polymer	1. Microwave transparent 2. Heat resistant 3. Attractive 4. Moisture resistant 5. Chemical resistant 6. Rigid	1. Food portion trays	1. Plastics, Inc Box 3610 St Paul, Minn. 55165	Class I Class II (?)	2
L. Polyshrink	L D P E H D P E	1. Microwave transparent 2. Non-rigid 3. Low temperature tolerance 4. Moisture resistant	1. Resins 2. Films	1. Chemplex Co. Rolling Meadows Illinois 60008	Not Suitable	2

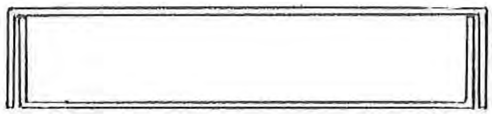
M. Poly-ether-sulfone	Thermo-plastic Poly-sulfone	1. Microwave transparent 2. High temperature 3. Attractive 4. Moisture resistant	1. Resins	1. Imperial Chem. Ind., Ltd. Welwyn Gardens Hertfordshire, England	Class I Class II (?)	2
N. Silent Service	foamed poly-styrene with poly-styrene film	1. Microwave transparent 2. Moisture resistant 3. Insulating 4. Attractive appearance 5. Low cost	1. trays 2. tableware	1. Sweetheart Cup Company Ownings Mills, Maryland	Class I	2
O. Texas-ware	Cellu-lose filled melamine	1. Microwave transparent 2. High temperature re-sistant 3. Moisture resistant 4. Attractive appearance 5. Rigid	1. Resins 2. Thermo-formed trays	1. Plastics Mfg. 2700 Westmore-land Dallas, Texas	Class II	2
P. Udel	Poly-sulfone	1. Microwave transparent 2. Heat resistant 3. Moisture resistant 4. Attractive appearance 5. Heat sealable 6. Chemical resistant 7. Somewhat expensive	1. Resins 2. Films 3. Thermo-formed trays 4. Injection molded	1. Union Carbide 270 Park Ave New York, NY 10017	Class I Class II (?)	2
Q. Valox	Thermo-plastic polyester	1. Microwave transparent 2. Heat resistant 3. Attractive appearance 4. Chemical resistant 5. Rigid 6. Not FDA	1. Resins	1. General Elec-tric Plastics Department 1 Plastics Ave. Pittsfield, Mass. 01201	Class II	2

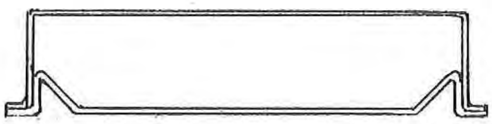
R. Vari-Pak	H D P E	1. Microwave transparent 2. Heat sealable 3. Moisture resistant 4. Semi-rigid 5. May perforate 6. Low cost	1. cartons 2. Trays	1. Sealright Co 605 W. 27th. Kansas City, Mo. 64112	Class I	2
S. Vydyne 20-N	66 Nylon	1. Microwave transparent 2. High heat resistant 3. Moisture resistant 4. Chemical resistant 5. Rigid	1. Resins	1. Monsanto 800 N.Lindburg St Louis, Mo. 63166	Class II (?)	2
T. Ranolon	Nylon	1. Microwave transparent 2. High heat resistant 3. Moisture resistant 4. Non-rigid	1. Film	1. Reynolds Metals Richmond, Va. 23261	Class I or II	2
U. Saran	Polyvin- ylidene Chloride	1. Low heat resistant 2. Moisture resistant 3. Non-rigid 4. Heat shrinking	1. Film	1. Dow Chem. Co Midland, Michigan 48640	Self- opening Covers	2
V. Scotch Pak #48 #105	Heat sealable polyester	1. Microwave transparent 2. Heat sealable 3. Moisture resistant 4. Non-rigid	1. Film	1. 3-M Company Film & Allied Products Div. st Paul, Minn. 55101	Class I or II as lids	2
W. Scotch Pak Oven film #5803	polyester	1. Microwave transparent 2. Chemical resistant 3. Heat resistant 4. Moisture resistant 5. Non-rigid	1. Film	1. 3-M Company Film & Allied Products Div. St Paul,Minn. 55101	Class II	2

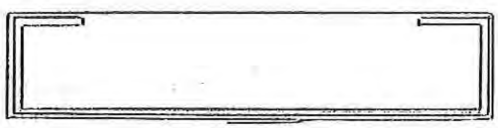
VII A.2 REPRESENTATIVE PACKAGE CONFIGURATIONS

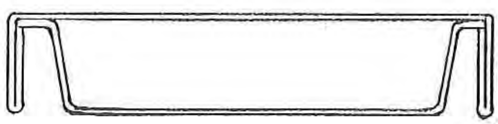
A. MICROWAVE ONLY - SERVE AS PACKED

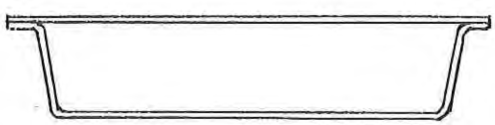
1.  One piece box

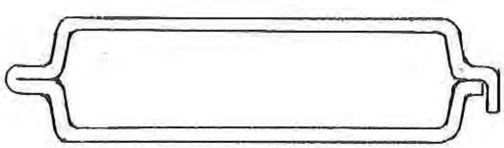
2.  Two piece telescoped box. (Shielding may be incorporated in either or both parts.)

3.  Top over formed tray

4.  Box in overwrap or bag

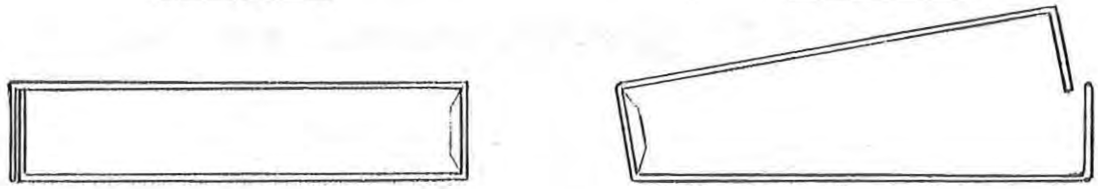
5.  Tray with edge lock cover

6.  Flat lid sealed to tray

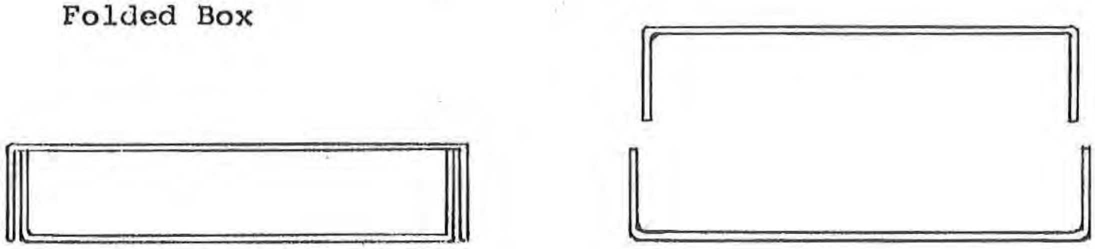
7.  Insulated package (May be other forms)

B. MICROWAVE ONLY - INVERT TO SERVE

AS PACKED | AS SERVED

1. 

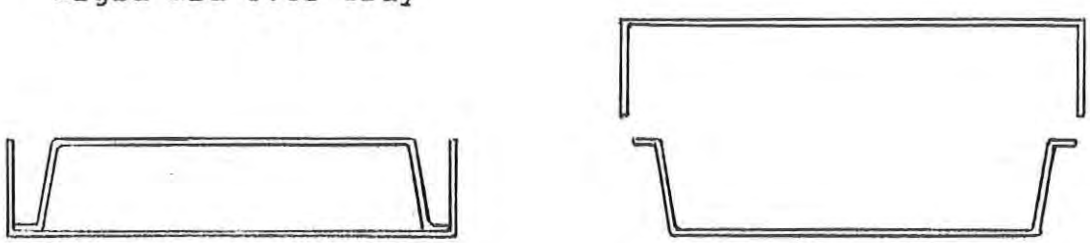
Folded Box

2. 

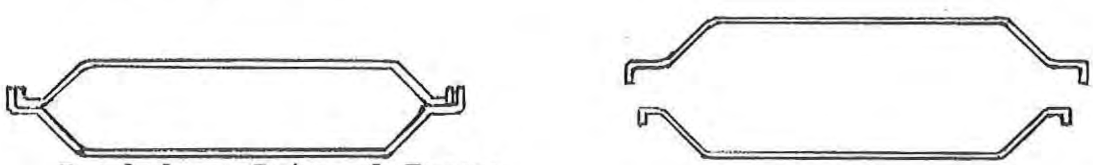
Telescoped Box

3. 

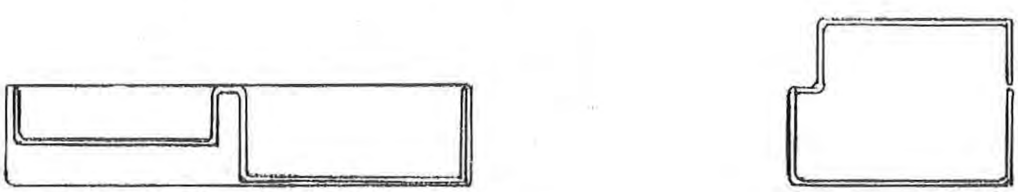
Rigid Lid over Tray

4. 

Supporting Cover over
Deep Tray

5. 

Bonded or Crimped Trays

6. 

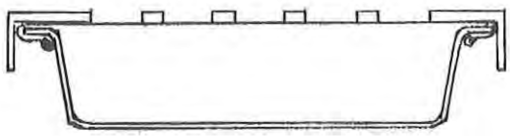
Partial Inversion (for
sandwiches or toppings)

C. MICROWAVE AND JET-CRISPER

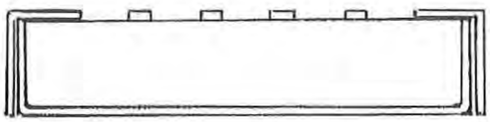
(May include microwave and/or jet shielding of selected areas)

1. 

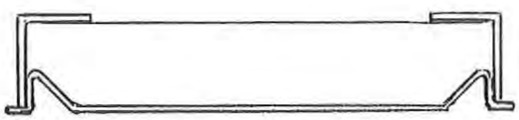
Heat sensitive film over-wrap. Box in a bag

2. 

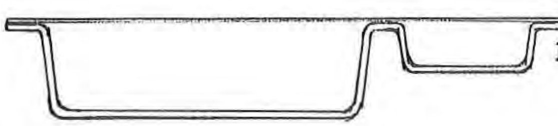
Shrink film over tray

3. 

Self-opening telescoping box

4. 

Heat perforating cover

5. 

Partial fold-over

6. 

Bake-in film in box

APPENDIX B. REPORTS OF EXPERIMENTS

CONSTRUCTION OF ICE BUCKET CALORIMETER

p. 51, Book 8 February 6, 1973

I. MATERIALS

A. Styrofoam ice bucket, approximately 7-inches high, 7½-inches in diameter with walls approximately 1-millimeter thick.

B. Styrofoam ice bucket, approximately 12½-inches high, 11-inches in diameter with walls approximately 1½-millimeter thick.

C. 1000-milliliter Pyrex Beaker.

D. Farenheit thermometer calibrated in tenths of degrees.

E. Styrofoam packing material.

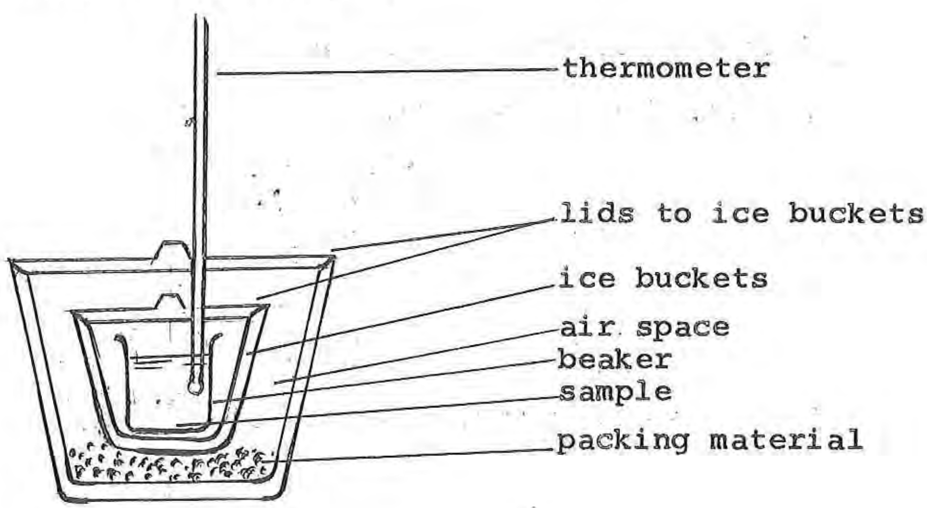
II. PROCEDURE

A. Punch hole about the diameter of thermometer in both lids.

B. Place smaller ice bucket inside larger, with packing material between bottoms of buckets. The air space is left between the walls.

C. Place sample in beaker. Place beaker in smaller ice bucket.

D. Place lids tightly on ice buckets, with thermometer positioned in sample and passing through holes in lids.



DEVELOPMENT OF ICE BUCKET CALORIMETER

p. 50, Book 8 February 6, 1973

I. MATERIALS AND PROCEDURE

A. Materials:

1. Ice Bucket Calorimeter
2. H_2O for sample

B. Procedure:

1. Place sample in calorimeter.
2. Note initial temperature of sample.
3. Note temperature at five minute intervals for thirty minutes.
4. Note change in temperature between initial and final readings.

II. RESULTS

A. Initial Temperature 110.6°F. at 3:40 p.m.

Time	Temperature (°F.)
3:45	109.4°
3:50	108.9
3:55	108.2
4:00	107.4
4:05	106.7
4:10	106.0

Heat loss in thirty minutes - 4.6°F.

B. Initial Temperature 84.9°F. at 3:58 p.m.

Time	Temperature (°F.)
4:03	84.7°
4:08	84.6
4:13	84.5
4:18	84.5
4:23	84.4
4:28	84.3

Heat loss in thirty minutes - .6°F.

C. Initial Temperature 109.8°F. at 9:35 a.m.

Time	Temperature (°F.)
9:40	109.0
9:45	108.6
9:50	108.3
9:55	107.8
10:00	107.8
10:05	106.8
10:10	106.8

Heat loss in thirty minutes - 3.0°F.

D. Initial Temperature 110.2°F. at 10:25 a.m.

Time	Temperature (°F.)
10:30	108.9
10:35	108.5
10:40	108.1
10:45	107.6
10:50	107.3
10:55	107.0

Heat loss in thirty minutes - 3.2°F.

E. Initial Temperature 51.0°F. at 11:35 a.m.

Time	Temperature (°F.)
11:40	51.0
11:45	51.1
11:50	51.2
11:55	51.3
12:00	51.5
12:05	51.7

Heat gain in thirty minutes - .7°F.

III. CONCLUSIONS

A. Heat loss in 30 minutes enough to indicate a reason.

B. Reason may be convection set up in air space between walls.

DEVELOPMENT OF THERMOS CALORIMETER

p. 53, Book 8 February 9, 1973

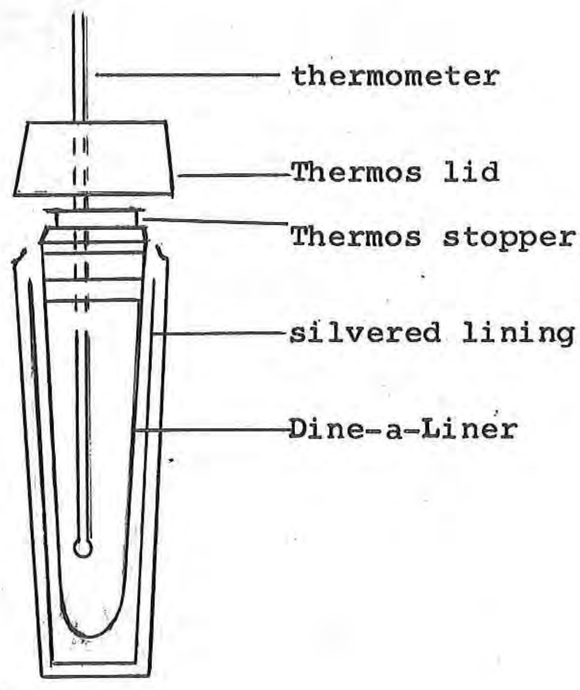
I. MATERIALS AND PROCEDURES

A. MATERIALS:

1. One quart size Thermos bottle with a Dine-a-liner.
2. Fahrenheit thermometer calibrated in tenths of degrees.
3. H_2O for sample.

B. PROCEDURE:

1. Drill hole in cap and stopper of Thermos the diameter of thermometer.
2. Place H_2O sample in Dine-a-liner.
3. Assemble Thermos, positioning thermometer through holes.



4. Note temperature change of H_2O sample at 5-minute intervals for 30 minutes.

5. Note change in initial temperature and final temperature of sample.

II. RESULTS

A. Initial Temperature 118.9°F. at 4:10 p.m.

Time	Temperature (°F.)
4:15	118.8
4:20	118.05
4:25	117.9
4:30	117.8
4:35	117.6
4:40	117.5

Heat loss in thirty minutes - 1.4°F.

B. Initial Temperature 119.1°F. at 10:32 a. m.

Time	Temperature (°F.)
10:37	118.1
10:42	117.45
10:47	117.2
10:52	117.1
10:57	117.0
11:02	116.9

Heat loss in thirty minutes - 1.2°F.

MEASURING HEAT TRANSFER IN FOOD SAMPLES

p. 53, Book 8 February 9, 1973

I. MATERIALS AND PROCEDURE

A. MATERIALS:

1. Thermos Calorimeter
2. Thermometer
3. Food Samples
4. H_2O

B. PROCEDURE:

1. Place selected volume of H_2O in Thermos. Allow to reach equilibrium.
2. Place food sample in water in Thermos. Allow to reach equilibrium.
3. Note initial temperature of H_2O, temperature change after final equilibration, temperature every 5 minutes.

II. RESULTS:

Green peas and ground beef at $0^{\circ}F$. were the food samples used.

A. H_2O only - Initial temperature $119.1^{\circ}F$. at 10:32 a.m.

Time	Temperature ($^{\circ}F$.)
10:37	118.1
10:42	117.4
10:47	117.2
10:52	117.1
10:57	117.0
11:02	116.9

H_2O + 3-ounces Peas (vigorously agitated with addition of peas) - Initial temperature $77.5^{\circ}F$. at 11:05 a.m.

Time	Temperature ($^{\circ}F$.)
11:10	78.2
11:15	80.1
11:20	81.1
11:25	82.1
11:30	83.1

Calorimeter and contents agitated vigorously at this point.

Time	Temperature ($^{o}F.$)
11:35	97.2
11:40	97.0
11:45	96.9
11:50	96.7
11:55	96.7

Calorimeter and contents agitated again - Temperature - $97^{o}F.$

Note: 1½-lbs H_2O + 3-ounce sample filled the bottle leaving 5/8-inch space at top. Sample could be shaken, however some water leakage occurred. Some heat loss around thermometer was suspected. Peas (except about 5) settled at bottom of container. Thermometer bulb positioned at bottom of container.

B. As A with following exceptions:

1. 1-3/8 pounds of H_2O instead of 1½ pounds.
2. Thermometer raised slightly so not touching bottom of container.
3. Agitation every five minutes with reading taken before and after each agitation.

H_2O only - Initial Temperature $119.6^{o}F.$ at 2:20 p.m.

Time	Temperature ($^{o}F.$)
2:25	119.3
2:30	118.6
2:35	118.4
2:40	118.3
2:45	118.2
2:50	118.1

H_2O - 3-oz Peas - Initial Temperature $118.1^{o}F.$ at 2:53 p.m.

Time	Temperature ($^{o}F.$) before Agitation	Temperature ($^{o}F.$) after Agitation
2:55	96.6	
3:00	96.0	98.0
3:05	98.0	98.1
3:10	98.05	98.05
3:15	98.0	98.0
3:20	98.0	97.9
3:25	97.9	97.85

C. As B with following exceptions:

1. 6-ounces ground beef instead of 3-ounces peas.
2. 1-pound H_2O instead of 1-3/8 pound.

H_2O only - Initial Temperature - 119.7°F. at 3:35 p.m.

Time	Temperature (°F.) Before Agitation	Temperature (°F.) After Agitation
3:40	118.9	117.9
3:45	117.4	117.0
3:50	116.8	116.6
3:55	116.4	116.3
4:00	116.0	115.9

H_2O + Ground Beef - Initial Temperature 115.9°F. at 4:00 p.m.

4:05	76.9	77.0
4:10	76.9	77.2
4:15	77.2	77.5
4:20	77.5	77.7
4:25	77.7	77.8

PREPARATION OF STANDARD USING PLASTIC BOTTLE

p. 31, Book 8 January 5, 1973

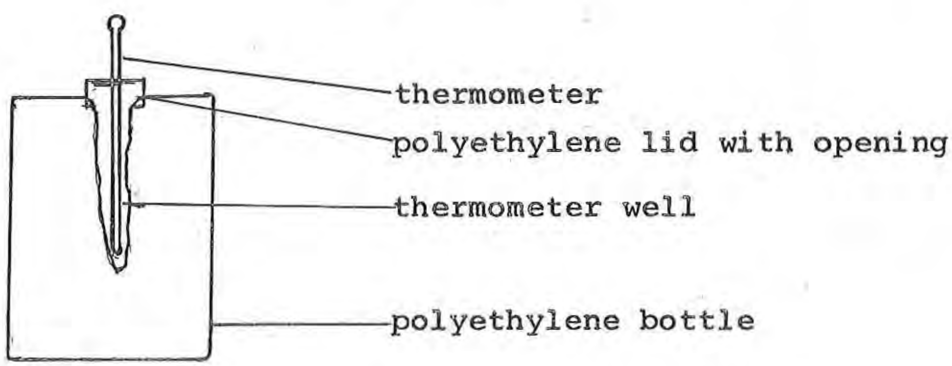
I. MATERIALS AND PROCEDURE

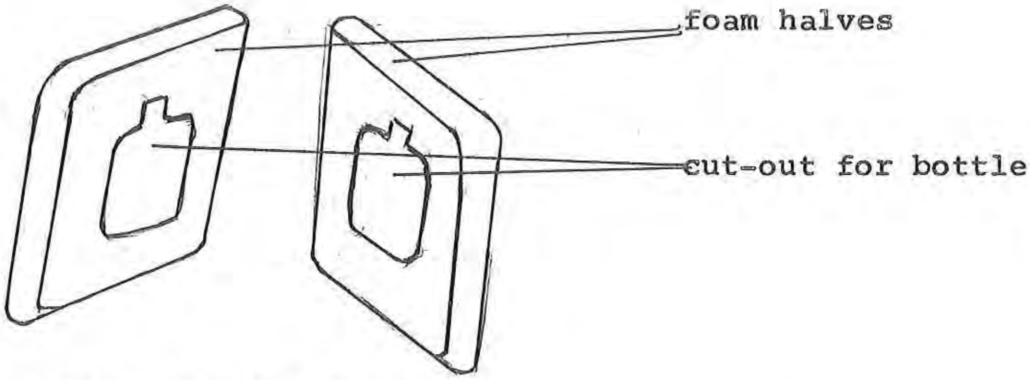
1. 16-ounce polyethylene bottle of a rectangular shape.
2. Polyethylene lid with opening.
3. Thin latex finger cots or phrophylactics for thermometer well.
4. Thermometer
5. Foam insulator
6. Test substances

PROCEDURE:

1. Pour selected quantities of test substance into bottle.
2. Place thermometer well in bottle and attach lid.
3. Place bottle in insulator.
4. Heat entire package in microwave for selected length of time.
5. Place thermometer in well immediately upon removing from oven.
6. Calculate Btu/minute.

$$\text{Weight (Lbs)} \times \Delta T\ {}^{\circ}F \times \frac{60\ \text{Sec.}}{\text{Time in Sec.}} \times \text{Sp. Heat } H_2O = \text{Btu/Min.}$$





FOAM INSULATOR BOX

II. RESULTS

A. The following tests were performed in Sharp R6500A 20703195 CM for 1 minute using 12-oz each tap water and .01% NaCl solution. The first two determinations were made with the foam envelope, the second two without.

Test	Solution	Beg. Temp (°F.)	Final Temp. (°F.)	ΔT	Btu/Min.	Temp.(°F.) 1-min.Later
1.	Tap	64	99	35	26.4	99
	NaCl	70	107	37	36.9	106
2.	Tap	68	106	38	37.5	105
	NaCl	70	104	34	34.5	
3.	Tap	65	95	30	22.5	
	NaCl	70	107	23	17.4	
4.	Tap	65	101	36	27.0	
	NaCl	72	109	39	29.4	

B. The following tests were performed in Litton 550 ASD 2990 for 30 seconds using 12-oz each tap water and .01% NaCl solution.

1.	Tap	66	107	41	61.8	
	NaCl	72	112	40	60.0	
2.	Tap	67	106	39	67.8	
	NaCl	71	111	40	60.0	

III. CONCLUSIONS:

A. This package is insulated so that heat loss is slow.

B. Heat measurements taken using this package are fairly accurate.

NOTE: Varying amounts of test material may be used; however, with small amounts that heat rapidly to a high temperature, the steam created pushes the thermometer well against the lid opening. This makes it difficult to insert the thermometer without breaking the well.

MEASURING ACTUAL BTU'S REQUIRED
TO HEAT SPECIFIC FOOD PORTION

p. 36, 38, Book 8 January 24, 1973

I. MATERIALS AND PROCEDURE

A. MATERIALS:
1. Standard Package using bottle
2. Food Samples
3. Bimetal thermometer

B. PROCEDURE:
1. Measure and refrigerate appropriate weights of food samples.
2. Place sample in bottle and assemble package. Note beginning temperature.
3. Heat sample in microwave for selected times until desired temperature is reached.
4. Note:
   a. Time required to reach desired temperature or temperature at which heating was terminated.
   b. Temperature at which heating was terminated.
   c. ΔT
5. Calculate Btu according to following formula:

$$\text{Weight (Lbs)} \times \Delta T\ ^{\circ}F \times \frac{60\ \text{Sec.}}{\text{Time in Sec.}} \times \text{SP.Heat } H_2O = \text{Btu/Min.}$$

II. RESULTS:

A. 3-ounce portions of green peas, 6-ounce portions of ground beef were food samples used.
B. Determinations were made in Litton Model 550 151-3.
C. Desired temperature for all tests was 160°F.

PRODUCT	TIME INTERNAL	BEGINNING TEMP. (^{o}F.)	FINAL TEMP. (^{o}F.)	ΔT	BTU/MIN
Ground Beef	30 Sec.	41	143	Thermometer well broke voiding test	
Ground Beef	40 Sec.	39	163	124	31.0
Ground Beef	40 Sec.	41	170	130	32.5
Ground Beef	40 Sec.	44	166	122	30.5
Average Btu/Minute - 31.5					
Green Peas	20 Sec.	49	161	112	14.79
Green Peas	20 Sec.	50	160	110	
Green Peas	20 Sec.	47	158	111	
D. Following determination made in Sharp R6500A 20702879 using 3-ounces green peas:					
Green peas	40 Sec.	48	146	98	
Green Peas	45 Sec.	46	159	113	
Green Peas	45 Sec.	46	162	116	
Green Peas	45 Sec.	46	161	115	

III. CONCLUSIONS:

A. Litton Microwave oven, model 550-151-3 heats 3- and 6-ounce portions to 160^{o}F. within two minutes.

B. Sharp Microwave oven, Model R6500A 20702879 heats 3-ounce portions to 160^{o}F. within two minutes.

PREPARATION AND USE OF A STANDARD PACKAGE USING A GUSSET BAG DESIGN

February 19, 1973

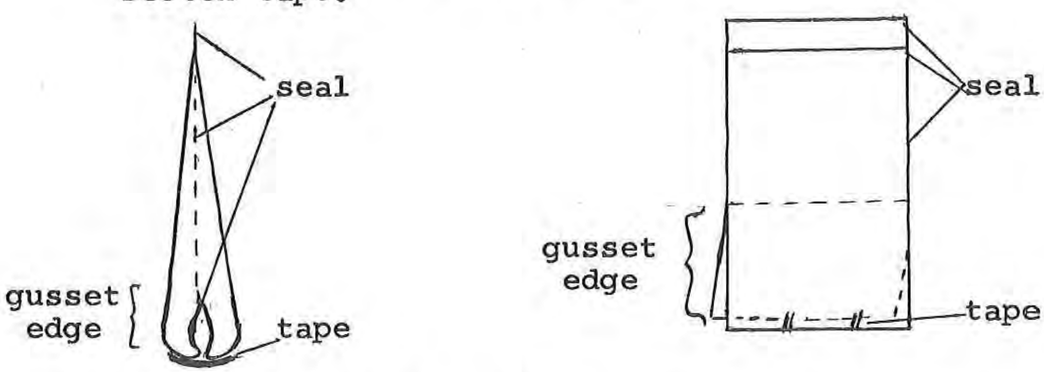
I. MATERIALS AND PROCEDURE:

A. MATERIALS:

1. Polypropylene-nylon laminated film
2. Scotch tape
3. Pyrometer with thermocouple
4. Device for sealing bags (Iron)
5. Insulating box made of foam

B. PROCEDURE:

1. Make gusset bottom bag of laminate approximately 5½-inches wide between seals, 8-inches long, with gusset approximately 2-5/8 inches deep. Secure sides with sealing device. Secure bottom edges of gusset with scotch tape.



2. Fill bag with selected amount of sample; In this test, water was used. Seal top edge.
3. Place thermocouple tip in well created by gusset edges.
4. With thermocouple in place, put bag in insulator box. Put it in oven.
5. Bring thermocouple to outside through hole in oven wall. Connect to pyrometer. Note beginning temperature of sample.
6. Operate oven for selected length of time, 30 seconds for this test.

7. Note final temperature of sample five minutes after oven ceases operation.

NOTE: Sensing unit of thermocouple must be in good contact with contents of bag.

	WEIGHT H_2O	BEGINNING TEMP. (°F.)	FINAL TEMP. (°F.)	ΔT	Btu/MIN.
#1	2 oz	75	138	63	15.75
	4 oz	50	94	44	22.00
	6 oz	58	89	31	23.84
	8 oz	58	83	25	25.00
	12 oz	59	80	21	31.50
	16 oz	62	75	13	26.00
	32 oz	58	60	02	08.00
#2	2 oz	55	109	54	
	4 oz	58	100	42	
	6 oz	60	90	30	
	8 oz	55	85	30	
	12 oz	53	68	15	
	16 oz	50	58	08	
	32 oz	50	58	08	
#3	2 oz	44	110	66	16.50
	4 oz	42	88	46	23.00
	6 oz	40	72	32	24.00
	8 oz	40	68	28	28.00
	12 oz	40	60	20	30.00
	16 oz	40	56	16	32.00
	32 oz	52	59	07	28.00

III. CONCLUSIONS:

A. This is a fairly satisfactory method for measuring the temperature of a sample inside the microwave field.

B. This will also provide a satisfactory method for measuring the temperature of a sample after heating as the insulating box allows the sample to equilibrate for a desired length of time without heat loss.

MEASURING POWER INPUT TO VARIOUS SIZE PORTIONS
IN LITTON MICROWAVE OVEN MODEL 550 151-3

p. 77, Book 8 March 8, 1973

I. MATERIALS AND PROCEDURE

A. MATERIALS:

1. Gusseted bags containing 2, 4, 6, 8, 12 and 16-oz H_2O respectively
2. Insulator box
3. Bimetal Thermometer

B. PROCEDURE:

1. Place sample (appropriate volume of H_2O in bag) in insulator box.
2. Place thermometer sensing device through well of box and between flaps of gusset. Note initial temperature.
3. Remove thermometer. Heat in oven for selected length of time.
4. Remove box with sample from oven. Replace thermometer according to Step 2. Note final temperature.
5. Calculate Btu's/minute using following formula:

$$\text{Weight (Lbs)} \times \Delta T\ {}^{o}F. \times \frac{60 \text{ Sec.}}{\text{Time in Sec.}} \times \text{Sp.Heat } H_2O = \text{Btu/Min}$$

II. RESULTS:

All final temperatures were allowed five minutes to equilibrate; all samples were heated for fifteen seconds.

	WEIGHT H_2O	BEGINNING TEMP.(°F.)	FINAL TEMP.(°F.)	ΔT	BTU/MIN
#1	2 oz	39	133	94	47
	4 oz	39	92	53	53
	6 oz	40	79	39	58.5
	8 oz	40	66	26	52
	12 oz	40	60	20	60
	16 oz	41	57	16	64
#2	2 oz	42	140	98	49
	4 oz	40	92	52	52
	6 oz	42	78	36	54
	8 oz	44	69	25	50
	12 oz	43	63	20	60
	16 oz	44	57	13	52
#3	2 oz	47	137	90	45
	4 oz	47	98	51	51
	6 oz	49	89	35	52.5
	8 oz	47	72	25	50
	12 oz	52	72	20	60
	16 oz	54	68	14	56
#4	2 oz	38	128	90	45
	4 oz	54	107	53	53
	6 oz	50	83	33	49.5
	8 oz	51	77	26	52
	12 oz	47	66	19	57
	16 oz	59	71	12	48

<u>Average Btu/Minute</u>

2 oz - 46.5
4 oz - 52.25
6 oz - 53.65
8 oz - 51.0
12 oz - 59.25
16 oz - 55.0

MEASURING POWER INPUT TO VARIOUS SIZE PORTIONS IN LITTON MICROWAVE OVEN, MODEL 550 AND 2990

p. 73, Book 8 March 5, 1973

I. MATERIALS AND PROCEDURE

A. MATERIALS:

1. Gusseted bags containing 2,4,6,8,12, 16, and 32 ounces H_2O respectively.
2. Insulator box
3. Bimetal thermometer

B. PROCEDURE:

1. Place sample (appropriate volume of H_2O in bag) in insulator box.
2. Place thermometer sensing device through well of box and between flaps of gusset. Note initial temperature.
3. Remove thermometer. Heat in oven for selected length of time.
4. Remove box and sample from oven. Replace thermometer according to Step 2. Note final temperature.
5. Calculate the Btu/Minute by following formula:

$$\text{Weight (Lbs)} \times \Delta T\ {}^{o}F \times \frac{60\ \text{Sec.}}{\text{Time in Sec.}} \times \text{SP.Heat } H_2O = \text{Btu/Min.}$$

II. RESULTS - All final temperatures were allowed 5 minutes to equilibrate; samples exposed for 15 seconds.

	WEIGHT	BEGINNING TEMP. (°F.)	FINAL TEMP. (°F.)	ΔT	BTU/MIN
#1	2 oz	46	140	94	47.0
	4 oz	39	95	56	56.0
	6 oz	40	77	37	55.5
	8 oz	45	79	34	68.0
	12 oz	37	58	21	63.0
	16 oz	37	56	19	76.0
#2	2 oz	51	142	91	45.5
	4 oz	52	104	52	52.0
	6 oz	49	92	43	64.5
	8 oz	49	82	33	66.0
	12 oz	49	73	24	72.0
	16 oz	49	69	20	80.0
#3	2 oz	42	135	93	46.5
	4 oz	40	95	55	55.0
	6 oz	36	76	40	60.0
	8 oz	38	71	33	66.0
	12 oz	40	61	21	63.0
	16 oz	40	58	18	72.0
#4	2 oz	46	133	87	43.5
	4 oz	48	83	35	35.0
	6 oz	48	87	39	58.5
	8 oz	47	77	30	60.0
	12 oz	48	69	21	63.0
	16 oz	46	65	19	76.0

<u>Average Btu/Minute</u>

2 oz	-	45.5
4 oz	-	55.5
6 oz	-	59.6
8 oz	-	65.0
12 oz	-	65.25
16 oz	-	76.0

MEASURING POWER INPUT TO VARIOUS SIZE PORTIONS

IN SHARP MICROWAVE OVEN R6500A 20703195 CM

p. 74, Book 8 March 5, 1973

I. MATERIALS AND PROCEDURE

A. MATERIALS:

1. Gusseted bags containing 2, 4, 6, 8, 12, 16, and 32 oz H_2O respectively.
2. Insulator Box
3. Bimetal Thermometer

B. PROCEDURE:

1. Place sample (appropriate volume of H_2O in bag) in insulator box.
2. Place thermometer sensing device through well of box and between flaps of gusset. Note initial temperature.
3. Remove thermometer. Heat in oven for selected length of time.
4. Remove box with sample from oven. Replace thermometer according to Step 2. Note final temperature.
5. Calculate Btu's/Minute by following formula:

$$\text{Weight (Lbs)} \times \Delta T\ {}^{o}F \times \frac{\text{60 Sec.}}{\text{Time in Sec.}} \times \text{Sp.Heat } H_2O = \text{Btu/Min.}$$

II. Results

All final temperatures were allowed 5 minutes to equilibrate; samples were heated for 30 seconds.

	WEIGHT H_2O	BEGINNING TEMP. (°F.)	FINAL TEMP. (°F.)	ΔT	BTU/MIN
#1	2 oz	75	138	63	15.75
	4 oz	50	94	44	22.00
	6 oz	58	89	81	23.84
	8 oz	58	83	25	25.00
	12 oz	59	80	21	31.50
	16 oz	62	75	13	26.00
#2	2 oz	55	109	54	
	4 oz	58	100	42	
	6 oz	60	90	30	Dubious
	8 oz	55	85	30	Results
	12 oz	53	68	15	
	16 oz	50	58	08	
#3	2 oz	44	110	66	16.5
	4 oz	42	88	46	23.0
	6 oz	40	72	32	24.0
	8 oz	40	68	28	28.0
	12 oz	40	60	20	30.0
	16 oz	40	56	18	32.0

Average Btu/Minute

2 oz - 16.12
4 oz - 22.50
6 oz - 23.92
8 oz - 26.50
12 oz - 30.75
16 oz - 29.00

MEASURING POWER INPUT TO VARIOUS SIZE PORTIONS

IN SHARP MICROWAVE OVEN R6500A 20703195 CM

p. 74, Book 8 March 5, 1973

I. MATERIALS AND PROCEDURE

A. MATERIALS:

1. Gusseted bags containing 2, 4, 6, 8, 12, 16, and 32 oz H_2O respectively.
2. Insulator Box
3. Bimetal Thermometer

B. PROCEDURE:

1. Place sample (appropriate volume of H_2O in bag) in insulator box.
2. Place thermometer sensing device through well of box and between flaps of gusset. Note initial temperature.
3. Remove thermometer. Heat in oven for selected length of time.
4. Remove box with sample from oven. Replace thermometer according to Step 2. Note final temperature.
5. Calculate Btu's/Minute by following formula:

$$\text{Weight (Lbs)} \times \Delta T\ {}^{o}F \times \frac{\text{60 Sec.}}{\text{Time in Sec.}} \times \text{Sp.Heat } H_2O = \text{Btu/Min.}$$

II. RESULTS

All final temperatures were allowed 5 minutes to equilibrate; determinations 1 & 2 were exposed for 30 seconds, 3 & 4 for 1 minute.

	WEIGHT H_2O	BEGINNING TEMP. (°F.)	FINAL TEMP. (°F.)	ΔT	BTU/MINUTE
#1	2 oz	50	112	62	15.5
	4 oz	48	83	35	17.5
	6 oz	49	80	31	23.25
	8 oz	46	69	23	23.0
	12 oz	48	66	18	27.0
	16 oz	28	42	14	28.0
#2	2 oz	32	96	64	16.0
	4 oz	30	69	39	19.5
	6 oz	34	63	29	21.75
	8 oz	31	54	23	23.0
	12 oz	30	49	19	28.5
	16 oz	37	51	14	28.0
#3	2 oz	40	165	125	15.62
	4 oz	33	120	87	21.75
	6 oz	30	93	63	23.62
	8 oz	30	82	52	26.00
	12 oz	32	68	36	27.00
	16 oz	32	62	30	30.00
#4	2 oz	42	150	108	13.5
	4 oz	38	110	72	18.0
	6 oz	28	84	56	21.0
	8 oz	39	88	49	24.5
	12 oz	29	68	39	29.25
	16 oz	47	73	26	26.0

<u>Average Btu's/Minute</u>

2 oz - 15.15
4 oz - 19.17
6 oz - 22.44
8 oz - 24.12
12 oz - 27.93
16 oz - 28.00

MEASURING POWER INPUT TO VARIOUS SIZES OF PORTIONS WITH VARYING DEGREES OF IONIZATION

p. 29, Book 8 January 14, 1973

I. MATERIALS AND PROCEDURE

A. MATERIALS:

1. Styrofoam
2. Polyethylene Containers
3. Bimetal Thermometer
4. Distilled Water
5. Tap water
6. 1% Na Cl Solution

B. PROCEDURE:

1. Prepare NaCl Solution (5-3/4 tsp. NaCl + 96-oz H_2O
2. Place 2, 4, 5-1/3, 8, 16, 24, 32-oz of solution being tested into polyethylene cup. Note initial temperature.
3. Position cup on foam plate in oven. Cover with foam cap.
4. Operate oven for selected length of time.
5. Remove cup and note final temperature.
6. Calculate Btu/Minute according to following formula:

$$\text{Weight (Lbs)} \times \Delta T\ {}^{\circ}F. \times \frac{60\ \text{Sec.}}{\text{Time in Sec}} \times \text{Sp.Heat } H_2O = \text{Btu/Min.}$$

II. RESULTS

A. Distilled water, samples heated in Litton microwave oven, model 550 151-30 for 30 seconds.

	WEIGHT H_2O (oz)	BEGINNING TEMP. (°F.)	FINAL TEMP.(°F.)	ΔT	BTU/MINUTE
#1	2 oz	72	166	94	23.5
	4 oz	72	164	92	46.0
	5-1/3 oz	74	142	68	45.3
	8 oz	74	128	54	54.0
	16 oz	74	107	33	66.0
	24 oz	73	95	22	66.0
	32 oz	73	90	17	68.0

	WEIGHT H_2O (oz)	BEGINNING TEMP. (°F.)	FINAL TEMP. (°F.)	ΔT	BTU/MINUTE
#2	2 oz	74	187	113	28.2
	4 oz	75	165	90	45.0
	5-1/3 oz	75	145	70	46.6
	8 oz	75	132	57	57.0
	16 oz	74	105	31	62.0
	24 oz	74	95	21	63.0
	32 oz	74	90	16	64.0

Average Btu's/Minute

2 oz - 25.8
4 oz - 45.5
5-1/3 oz- 46.0
8 oz - 55.5
16 oz - 64.0
24 oz - 64.5
32 oz - 66.0

B. Tap water; 2, 4, 5-1/3, oz samples heated for 15 seconds. 8, 16, 24, 32 oz samples heated for 30 seconds.

#1	2 oz	63	162	99	49.5
	4 oz	60	110	50	50.0
	5-1/3 oz	58	105	47	62.4
	8 oz	58	115	57	57.0
	16 oz	58	88	30	60.0
	24 oz	58	82	24	72.0
	32 oz	57	75	18	72.0
#2	2 oz	58	162	104	52.0
	4 oz	57	115	58	58.0
	5-1/3 oz	58	104	46	61.2
	8 oz	58	114	58	56.0
	16 oz	57	88	31	62.0
	24 oz	58	81	23	69.0
	32 oz	58	75	17	68.0

Average Btu's/Minute

2 oz - 50.7
4 oz - 54.0
5-1/3 oz- 61.8
8 oz - 56.5
16 oz - 61.0
24 oz - 70.5
32 oz - 70.0

C. 1% Na Cl Solution; 2, 4, 5-1/3 oz samples heated for 15 seconds. 8, 16, 24, 32-oz samples heated for 30 seconds.

	WEIGHT H_2O (oz)	BEGINNING TEMP. (°F.)	FINAL TEMP. (°F.)	ΔT	BTU/MINUTE
#1	2 oz	59	165	106	53.2
	4 oz	58	112	54	54.0
	5-1/3 oz	58	102	44	74.8
	8 oz	58	116	58	58.0
	16 oz	58	88	30	60.0
	24 oz	58	81	23	69.0
	32 oz	59	76	17	68.0
#2	2 oz	59	168	109	54.4
	4 oz	58	110	52	52.0
	5-1/3 oz	58	105	47	62.0
	8 oz	58	117	59	59.0
	16 oz	58	90	32	64.0
	24 oz	59	82	23	69.0
	32 oz	59	75	16	64.0

<u>Average Btu's/Minute</u>

2 oz	- 53.8
4 oz	- 53.0
5-1/3 oz	- 68.4
8 oz	- 58.5
16 oz	- 62.0
24 oz	- 69.0
32 oz	- 66.0

DEVELOPMENT OF TECHNIQUE FOR MEASURING

TEMPERATURE INSIDE THE MICROWAVE FIELD

p. 59, Book 8 February 14, 1973

I. MATERIALS AND PROCEDURE

A. MATERIALS:

1. 32-ounces square HDPE box
2. Pyrometer
3. Pyrometer leads sleeved in Teflon tubing

B. PROCEDURE:

1. Puncture box above liquid line.
2. Place selected amount of water in box, place in oven.
3. Insert pyrometer lead into cavity through opening in wall.
4. Place tip of lead through opening in box into sample; Note beginning temperature.
5. Heat sample selected length of time, or until desired temperature is reached; note either end temperature or time required, whichever is appropriate.
6. Check for difference in actual final temperature of water, and temperature of metal lead tip:

   a. Heat one sample without lead in place; measure temperature by thermometer.
   b. Heat one sample with lead in place.
   c. Note difference in final temperature.

II. RESULTS

A. Difference in actual end temperature.

The following test was performed in a modified Litton 500 (Crisper prototype) for one minute using sixteen ounces of water as the test material.

	BEGINNING TEMP. (^{o}F.)	FINAL TEMP. (^{o}F.)
Without thermocouple (Bimetal thermometer)	56	81
With thermocouple	56 (thermometer)	75 (thermocouple)
#1		60 (thermometer)
#2	49	85 (both by thermometer)
#3	50	80

B. FINDING END POINT TIME:

The following test was performed in a modified Litton 500 (Crisper Prototype) using water samples sealed in bag of polypropylene-mylar lamination vented to allow for steam development. Energy was applied to the sample until the desired end point was reached, and the time required to reach this end point was noted.

	BEGINNING TEMPERATURE (^{O}F.)	TIME REQUIRED TO REACH 160^{O}F.
#1	35	About 90 seconds to reach 190^{O}F.
#2	Void	
#3	35	123.5 seconds to reach 180^{O}F. (Went to 140 in 45 seconds; back to 155 upon vigorous shaking. Equilibrated at 155.)

MEASURING POWER OUTPUT USING

THERMOCOUPLE IN MICROWAVE FIELD

p. 62, Book 8 February 16, 1973

I. MATERIALS AND PROCEDURE

A. MATERIALS:

1. Bags of polypropylene and mylar laminate
2. Heat sealing device
3. Foam insulator
4. Pyrometer with thermocouple sleeved in Teflon.

B. PROCEDURE:

1. Place 50 milliliters H_2O in each of two bags. Heat seal.
2. Place bags one on top of the other in foam insulator with thermocouple positioned between them.
3. Operate microwave for 10 seconds. Shake package vigorously.
4. Note:
   a. Temperature at end of initial 10 seconds.
   b. Temperature change at end of several minutes equilibration time.
5. Calculate power according to following formula:

$$p = 2.33 \left(\frac{\text{vol. cc}}{\text{time sec.}}\right) \Delta TF$$

$\frac{\text{Vol. cc}}{\text{Time Sec.}}$ must equal 10. Example: $\frac{200 \text{ ml}}{20 \text{ Sec}} = 10$

II. RESULTS

	VOLUME	TIME	BEG. TEMP	FINAL TEMP	ΔT	POWER
#1	100 ml	10 Sec.	58	79	21	$2.33 \left(\frac{100}{10}\right) 21 = 489.3$
#2	100 ml	10 Sec.	60	Void - Seal broke		
#3	100 ml	10 Sec.	52	80	28	$2.33 \left(\frac{100}{10}\right) 28 = 652.4$

FINDING END POINT TIME BY MEASURING

TEMPERATURE IN THE MICROWAVE FIELD

p. 60, Book 8 February 15, 1973

I. MATERIALS AND PROCEDURE

A. MATERIALS:

1. Bags of polypropylene-mylar laminate
2. Sealing Device
3. Food samples
4. Pyrometer
5. Leads sleeved in Teflon

B. PROCEDURE:

1. Seal appropriate weights of food samples in bags, venting to allow for development of steam.
2. Arrange bag in oven with pyrometer lead placed through bag so tip is imbedded in the sample.
3. Operate microwave until desired end point is reached. Stop microwave and note length of time required to reach this temperature. A stop watch is helpful.
4. Note:
   a. Length of time and amount of temperature change in equilibration.
   b. Change in equilibration after vigorous agitation.

II. RESULTS: - 6-ounce ground beef was food sample used.

	BEGINNING TEMP. (^{o}F.)	TIME TO 180^{o} F.	EQUIL. TIME	EQUIL. TEMP (^{o}F)	AFTER SHAKING	3-MIN. LATER
#1	35	1 min 43 sec.	30 sec	120^{o}	130^{o}	125^{o}
#2	35	2 min 34 sec.	30 sec	160^{o}	165^{o}	160^{o}
#3	35	2 min 11 sec.	30 sec	140^{o}	150^{o}	150^{o}
		Foam Insulator used on Following Tests				
#4	35	1 min 14½sec.		170^{o}	165^{o}	155^{o}
#5	32	2 min 10 sec.	180^{o}/2 min	180^{o}	165^{o}	170^{o}
#6	35	1 min 9⅓ sec. (to 160^{o}F.)	20^{o} loss in first 2 min.	135^{o}	135^{o}	135^{o}
#7	32	2 min 5 sec.	15^{o} loss in first 2 min.	165^{o}	169^{o}	169^{o}

NOTE: #4 was used to attempt to observe a pattern in heat loss. The temperature dropped 5 degrees every 30 seconds for first 2 minutes after microwave was halted, then continued to drop, but very slowly.

CONCLUSION:

This technique needs more refinement to be useful in predicting times required to reach desired temperatures.

MEASURING POWER INPUT TO VARIOUS SIZE PORTIONS IN LITTON 550 ASD 2990 INSIDE MICROWAVE FIELD

p. 64, Book 8 February 20, 1973

I. MATERIALS AND PROCEDURE

A. MATERIALS:

1. Gusseted bags containing 2, 4, 6, 8, 12, 16- oz H_2O respectively.
2. Insulator Box
3. Pyrometer with thermocouple

B. PROCEDURE:

1. Sleeve pyrometer lead in Teflon tubing. Place sensing device in cavity through hole in wall of oven. Connect other end of lead to pyrometer.
2. Place sample in box, place in oven.
3. Position thermocouple tip through well in box between flaps of gusset. Note initial temperature.
4. With thermocouple in place, operate oven for selected length of time. Note final temperature.
5. Calculate Btu's/Minute using following formula:

$$\text{Weight (Lbs)} \times \Delta T\ {}^{\circ}F \times \frac{60 \text{ Sec.}}{\text{Time in Sec.}} \times \text{Sp.Heat } H_2O = \text{Btu/Min.}$$

II. RESULTS:

All final temperatures were allowed 5 minutes to equilibrate; samples were heated for 30 seconds.

	WEIGHT H_2O (oz)	BEGINNING TEMP. (°F)	FINAL TEMP (°F)	ΔT	Btu/MIN
#1	2 oz	75	138	63	15.75
	4 oz	50	94	44	22.00
	6 oz	58	89	31	23.84
	8 oz	58	83	25	25.00
	12 oz	59	80	21	31.50
	16 oz	62	75	13	26.00

	WEIGHT H_2O (oz)	BEGINNING TEMP (^oF)	FINAL TEMP (^oF)	ΔT	BTU/MIN
#2	2 oz	55	109	54	
	4 oz	58	100	42	
	6 oz	60	90	30	Dubious
	8 oz	55	85	30	Results
	12 oz	53	68	15	
	16 oz	50	58	08	
#3	2 oz	44	110	66	16.5
	4 oz	42	88	46	23.0
	6 oz	40	72	32	24.0
	8 oz	40	68	28	28.0
	12 oz	40	60	20	30.0
	16 oz	40	56	18	32.0

Average Btu's/Minute

2 oz - 16.12
4 oz - 22.50
6 oz - 23.92
8 oz - 26.50
12 oz - 30.75
16 oz - 29.00

MEASURING ENERGY REQUIREMENT TO HEAT VEGETABLE PORTIONS TO 160°F.

p. 68 Book 8 February 23, 1973

I. MATERIALS AND PROCEDURE

A. MATERIALS:

1. Polypropylene-mylar laminate
2. Heat sealing device
3. Vegetable samples
4. Pyrometer with thermocouple sleeved in Teflon
5. Insulator box

B. PROCEDURE:

1. Prepare both gusseted bags and fold-over bags.
2. Fill with appropriate weight of sample. Seal, leaving steam vent.
3. Position bag in oven in insulator with thermocouple tip either between folds of gusset or between folds of fold-over bag.
4. Operate oven until desired temperature is reached. Stop microwave.
5. Note:

   a. Initial temperature
   b. Overrun temperature
   c. Time required to reach overrun temperature.
   d. Temperature after five minutes equilibration.
   e. Type bag used.

II. RESULTS

Following determinations were made in Sharp R6500A S/N 20702879 oven using three-ounce portions of vegetables.

	TYPE OF BAG	BEGINNING TEMPERATURE (^{O}F)	OVER-RUN TEMP (^{O}F)	TIME	TEMP (^{O}F) AFTER 5 MINUTES
#1	Foldover	38	180	Bag burst voiding test	
#2	Foldover	40	180	Bag burst voiding test	
#3	Gusset	42	180	1 min 10 sec	168
#4	Gusset	30	180	1 min 30 sec	190 - 200
#5	Gusset	35	180	1 min 5 sec	170
#6	Gusset	38	170	1 min 10 sec	180
	FOLLOWING TESTS WERE MADE USING 6-OZ GROUND BEEF				
#7	Gusset	26	180	3 min	Test voided
#8	Gusset	30	170	1 min 50 sec	160
#9	Gusset	23	170	2 min 20 sec	180
	FOLLOWING TESTS WERE MADE USING 3-OZ MASHED POTATOES IN GUSSETED BAGS				
#1		40	160	50 sec	120
#2		40	160	1 min 15 sec	168
#3		18	160	2 min 30 sec	170
#4		05	160	1 min	170
	FOLLOWING TESTS WERE MADE USING 3-OZ GREEN PEAS IN GUSSETED BAGS				
#5		32	160	1 min	170
#6		36	160	35 sec	130
#7		03	160	50 sec	35
#8		0	160	1 min	40
	FOLLOWING TESTS WERE MADE USING 3-OZ GREEN PEAS, MASHED, IN GUSSETED BAGS				
#9		38	160	1 min 10 sec	180
#10		25	160	1 min 35 sec	180

CONCLUSIONS:

This technique requires refinement before it is useful for predicting times required to reach desired temperatures.

THAWING FROZEN BEEF PORTIONS IN MICROWAVE

p. 56, Book 8 February 9, 1973

I. MATERIALS AND PROCEDURE

A. MATERIALS:
1. Beef roast
2. Bimetal thermometer

B. PROCEDURE:
1. Trim and divide roast into 4, 6, 8, oz portions. Freeze.
2. Heat sample for specified length of time.
3. Compare pulsing method of thawing with the one application of microwave to thaw.
4. Note temperature at center of sample and general condition of sample.

II. RESULTS

A. Heating done in Sharp R6500A 20702879

B. Samples between 1 and 1¼ inch thick.

WEIGHT (Oz)	THAWING METHOD	TIME	FINAL TEMP (°F)	GENERAL CONDITION
8	Pulsing	30 sec. on, off twice	0	Still frozen
8	Pulsing	30 sec. on, off 4 times	app. 40	Thawing
8	Pulsing	45 sec. on, off twice	40	Thawing
6	Pulsing	45 sec. on, Off twice	40 on one side 60 on other	
6	Pulsing	30 sec. on, off 3 times	40	Beginning to cook
8	Once	1½ minutes		Mostly thawed inside; beginning to cook on outside.
8	Once	2 minutes	55	Slight cooking on outside.
8	Once	1-3/4 min.	50	Less cooking on outside
12	Once	2 minutes	40	Some outside cooking

THAWING AND HEATING FOOD PORTIONS TO 160^{O}F.
IN MICROWAVE USING PULSING OR ONE APPLICATION

p. 97, Book 8 April 24, 1973

I. MATERIALS AND PROCEDURE

A. MATERIALS:

1. Chinet trays
2. Tray-Lite Trays
3. International Paper Meal-Eze Trays
4. Food samples
5. Insulator Box
6. Thermometer

B. PROCEDURE:

1. Package appropriate weight of food sample in each of above trays. Freeze.
2. Using time calculated for each product, use pulsing and one application of microwave so that time tube is actually in operation equals calculated time.
3. Allowing 5 minutes for equilibration in insulator box, note final temperature.

II. RESULTS

A. Samples heated in Litton 550 ASD 2990

B. Pulsing increments of 30 and 15 seconds used.

C. 6-oz samples were used for meat samples and 3-oz for vegetables.

PRODUCT	METHOD	TIME	BEGINNING TEMP (^{O}F)	FINAL TEMP (^{O}F)	CONTAINER
1. Fried Chicken	Once	1 min 27 sec	0	146	PE Board uncovered
2. Fried Chicken	Pulsed 30 sec. 3 times	1 min 27 sec	0	164	PE Board uncovered
3. Fried Chicken	Pulsed 15 sec 6 Times	1 min 27 sec	0	164	PE Board uncovered
4. Fried Chicken	Pulsed 15 sec 6 times	1 min 27 sec	0	152	PE Board uncovered
5. Turkey-dressing	Once	1 min 27 sec	0	70	PE Board uncovered
6. Turkey-dressing	Pulsed 30 sec.	1 min 27 sec	0	88	PE Board uncovered
7. Turkey-dressing	Pulsed 30 sec	1 min 27 sec	0	62	PE Board uncovered
8. Turkey-dressing	Pulsed 15 sec	1 min 27 sec	0	106	PE Board uncovered
9. Mashed potato	Once	53 sec	0	68	PP Board uncovered
10. Mashed potato	Once	53 sec	0	112	PP Board covered
11. Mashed potato	Pulsed 30 sec.	53 sec	0	98	PP Board covered
12. Mashed potato	Pulsed 15 sec.	53 sec	0	114	PE Board covered
13. Mashed potato	Pulsed 15 sec.	1 min	0	135	PE Board covered
14. Mashed potato	Pulsed 30 sec.	1 min	0	142	PE Board covered
15. Mashed potato	Pulsed 30 sec.	1 min 15 sec	0	142	PE Board covered
16. Mashed Potato	Pulsed 30 sec.	1 min 30 sec	0	156	PE Board covered
17. Mashed Potato	Once	1 min 30 sec	0	158	PE Board covered
18. Turkey	Pulsed 30 sec.	1 min 27 sec	0	122	PE Board uncovered

PRODUCT	METHOD	TIME	BEGINNING TEMP (°F)	FINAL TEMP (°F)	CONTAINER
19. Beef w Gravy (Ground)	Once	1 min 25 sec	0	106	Chinet-heat-sealed Lid
20. Beef w Gravy	Pulsed 30 sec.	1 min 25 sec	0	118	Chinet-Heat-sealed lid
21. Beef w Gravy	Pulsed 15 sec.	1 min 25 sec	0	114	Chinet-Heat-sealed lid
22. Beef w Gravy	Pulsed 30 sec.	2 min	0	162	Chinet-heat-sealed Lid
23. Sliced Beef w Gravy	Pulsed 30 sec.	2 min	0	118	Sealright Tray in bag
24. Beef w Gravy	Pulsed 30 Sec.	2 min	0	170	Chinet-Heat-sealed lid
25. Beef w Gravy	Pulsed 30 sec.	2 min	0	155	Chinet-Heat-sealed Lid
26. Beef w Gravy	Pulsed 30 sec.	2 min	0	130	Chinet-Heat-sealed Lid
27. Beef w Gravy	Pulsed 30 sec.	2 min	0	150	Chinet Heat-sealed Lid
28. Mashed Potato	Pulsed 30 sec.	2 min	0	178	Chinet-Heat-sealed Lid
29. Mashed Potato	Pulsed 30 sec.	1 min 45 sec	0	175	Chinet-Heat-sealed Lid
30. Mashed potato	Pulsed 30 sec.	1 min 30 sec	0	175	Chinet-Heat-sealed Lid
31. Fried Chicken	Pulsed 30 Sec.	1 min 30 sec	0	185	Chinet-Heat-sealed Lid
32. Green peas	Pulsed 30 sec.	1 min 30 sec	0	170	Round chinet heat-sealed Lid

33. Green peas	Pulsed 30 sec	1 min 15 sec	0	172	Round Chinet-Heat-seal Lid
34. Green Peas	Pulsed 30 sec.	1 min 15 sec	0	162	Chinet Tray heat-seal Lid
35. Mashed potato	Pulsed 30 sec.	1 min 30 sec	0	176	Round chinet-Heat-seal Lid

III. CONCLUSIONS

A. Pulsing to thaw is only one factor in bringing the portion from 0^{o}F. to 160^{o}F.

B. Choice of the containers tested does not seem to affect the heating.

C. Pulsing instead of a single application of microwave will not heat a portion to 160^{o}F. if the specified time is insufficient.

REHEATING FROZEN MEALS IN MICROWAVE AND CRISPER WITH MICROWAVE

p. 40, Book 8 January 30, 1973

I. MATERIALS AND PROCEDURE

A. MATERIALS:

1. Frozen meal
2. Plastic food portion trays
3. Thermometer

B. PROCEDURE:

1. Transfer frozen meal items to plastic tray for microwave, leave on aluminum for Food finisher.
2. Heat replated meal in microwave for 45 seconds, then let rest 45 seconds to thaw. Heat for specified time.
3. Note temperature of meal items, appearance, texture, color and shape.

II. RESULTS

Heating performed in Litton 550 151-3 and Food Finisher.

III. CONCLUSIONS

A. Meat products accompanied by liquid such as sauce or gravy were the most satisfactory in microwave.

B. Vegetable products were satisfactory in microwave alone, as were potato products except French fries.

C. Major problem with microwave alone in these tests was the presence of hot-cold spots.

D. Moisture escape, especially in microwave was a minor problem.

PRODUCT/WEIGHT	OVEN	TIME	BEGINNING TEMP (°F.)	FINAL TEMP (°F.)	COLOR	TEXTURE	GENERAL APPEARANCE
Swanson's Fried Chicken 11½ ounces	Food Finisher	3 min	44	178	Good		Good
Swanson's Egg & Sausage 6⅛ ounces	Food Finisher	3 min	43		Good	Bread, eggs tough Sausage good	Poor
Swanson's Spahgetti & Meatballs 12 ounces	Food Finisher	3 min			Good		Good
Swanson's Chinese 11 ounces	Food Finisher	3 min	41	140	Good		Good
Swanson's Meat Loaf & Potatoes 9 ounces	Litton	2 min	0	135	Good	Good	Fair, with hot-cold spots
Banquet Macoroni & Cheese 12 ounces	Litton	2 min	0	160	Excellent	Cheese chewy	Good with hot-cold spots
Swanson's Turkey & Dressing 8-3/4 ounces	Litton	2 min	0	160	Fair	Turkey dry potatoes fair	Poor-dry at edges
Swanson's Salisbury Steak	Litton	2 min	0	205	Fair	Steak dry French fries hard	Hot-cold spots somewhat evident, not as much as others

TESTING MICROWAVE HEATING OF FOODS, COVERED, FROM FROZEN

p. 84, Book 8 March 23, 1973

I. MATERIALS AND PROCEDURE

A. MATERIALS:

1. HDPE Trays
2. Film for Lids
3. Glue gun and hot melt glue
4. Food samples
5. Foam insulating box
6. Thermometer

B. PROCEDURE:

1. Place appropriate amount of sample in tray.
2. Attach film lid using bead of hot melt glue.
3. Freeze sample.
4. Heat sample in microwave for indicated length of time.
5. Place sample in insulator with thermometer in center. Allow to equilibrate for five minutes.
6. Note:

   a. Oven used
   b. Beginning temperature of sample
   c. Equilibrated temperature of sample
   d. Length of time heated
   e. Condition of food

II. RESULTS

Food samples used were mashed potatoes, green peas, green beans in butter sauce.

Ovens used were: Sharp R6500A 20703195 CM
Litton 550 ASD 2990

PRODUCT	OVEN	BEGINNING TEMP (°F)	FINAL TEMP (°F)	TIME (MIN)	CONDITION OF FOOD
Mashed potatoes	Litton	0	100	1 min	Hot & cold spots present
Green peas	Litton	0	160	1½ min	Good
Green peas in butter sauce	Litton	0	185	1½ min	Good
Mashed potatoes	Sharp	0	110	2 min	cold spots, frozen in center
Mashed potatoes	Sharp	0	108	2 min	cold spots, frozen in center
Green beans in butter sauce	Sharp	0	88	1½ min	Serious cold spots, completely thawed
Mashed potatoes	Litton	0	180	1½ min	Hot throughout

III. CONCLUSIONS

A. The high powered unit (Litton @1200 watts) gave more satisfactory results in 2 minutes than the low powered unit (Sharp @650 watts).

B. Mashed potatoes are difficult to heat.

HEATING PORTIONS FROM FROZEN TO SERVING, (UNCOVERED)

p. 83, Book 8 March 30, 1973

I. MATERIALS AND PROCEDURE

A. MATERIALS:

1. Microwave transparent food tray
2. Food samples
3. Foam Insulator
4. Thermometer

B. PROCEDURE:

1. Freeze appropriate amount of food sample in tray.
2. Check temperature of freezer at time of testing for $0^{o}F$.
3. Heat in microwave for indicated length of time.
4. Place sample in foam insulator with thermometer in center of sample. Allow to equilibrate for 5 minutes.
5. Note:
   a. Beginning temperature
   b. Equilibrated temperature of sample
   c. Desired temperature of sample
   d. Time in oven
   e. Oven used.

II. RESULTS

Food samples used were green peas, Tator-Tots, ground beef, and fried chicken.

Time was selected by calculations according to test of Book 8, p. 75.

Ovens used were: Sharp R6500A 20703195 CM
Litton 550 ASD 2990

PRODUCT	BEGINNING TEMP (^{O}F)	TIME	FINAL TEMP (^{O}F)	DESIRED TEMP (^{O}F)	OVEN
Peas	0	2 min 46 sec	150	160	Sharp
Tator-Tots	0	2 min 52 sec	166	160	Sharp
Ground Beef	0	1 min 25 sec	158	160	Litton
Ground Beef	0	1 min 25 sec	166	160	Litton
Fried Chicken	0	1 min 27 sec	150	160	Litton

III. CONCLUSIONS

A. Adequate or almost adequate heating time in Sharp exceeded two minutes.

B. Heating adequacy in specified time in Litton was borderline.

CALCULATION OF BTU'S REQUIRED TO HEAT SPECIFIC PORTION

p. 75, Book 8 March 6, 1973

Q = Btu Required
$Q = W(C \times (t_I - t_f) + h_f = C_7 (t_f - t_3))$
(WHEN:)
W = Weight of sample
C = Average specific heat below freezing
$t_i - t_f = \Delta T$ from freezing to thawing
h_f = Average latent heat
C_7 = Average specific heat above freezing
$t_f - t_3 = \Delta T$ from thaw to serving or final T

Time Required = $\frac{Q}{\text{Btu/Min}}$ for H_2O as seen on power curve

Sample Calculation of Time Required to heat 6-oz portion of Pork (p. 80):

$$Q = W(C\ (t_i - t_f) + h_f + C_7\ (t_f - t_3))$$
$$= 6/16(.38(0-29)+86.5 +.68(160-29))$$
$$= 6/16(11.02 + 86.5 + 89.08)$$
$$= 65.84 \text{ Btu}$$

Litton @ 1200-watts 6-ounce x $\frac{86.5}{144.0}$ = 3.6 ounce

Heat input to 3.6 oz H_2O in Litton is 50.5 Btu (located on curve)

$$\text{Time Required} = \frac{Q}{\text{Btu/Min}} = \frac{65.84}{50.5}$$

Time Required 6-oz pork = 1.30 min.

TIME REQUIRED TO HEAT EACH OF SPECIFIC FOOD ITEMS TO 160°F. IN 1200-WATT LITTON

p. 112, Book 8 June 5, 1973

I. MATERIALS AND PROCEDURES

A. MATERIALS:

1. Samples of Specified Foods
2. Heat seal Plastic bags
3. Insulator Box
4. Thermometer

B. PROCEDURE:

1. Weigh samples into bags. Seal. Freeze.
2. Heat for selected length of time.
3. Insert thermometer and hold in insulator for five minutes to equilibrate.
4. Note temperature

II. RESULTS

PRODUCT	TIME (MIN)	BEGINNING TEMP (°F)	FINAL TEMP (°F)	
1. Fried Chicken	2	0	205	
2. Fried Chicken	2	0	182	
3. Green Beans	1½	0	183	
4. Fried Chicken	2	0	198	
5. Roast Beef w Gravy	2	0	160	
6. Turkey & Dressing	2	0	125	Agitation
7. Turkey & Dressing	2½	0	180	Helps
8. Ham w Raisin Sauce	2	0	172	
9. Ham w Raisin Sauce	2	0	170	
10. Green Peas	1½	0	202	
11. Green Peas	1¼	0	187	
12. Green Peas	1	0	200	
13. Green Beans	1	0	180	
14. Pork w Gravy	2	0	168	
15. Broccoli	1	0	178	
16. Broccoli	1	0	185	
17. Creamed Peas & Carrots	1	0	162	

PRODUCT	TIME (MIN)	BEGINNING TEMP (^{o}F)	FINAL TEMP (^{o}F)
18. Creamed Peas & Carrots	1	0	139
19. Mashed potatoes	1	0	135
20. Mashed potatoes	1½	0	185
21. Boiled potatoes	1	0	145
22. Boiled potatoes	1½	0	157
23. Boiled Potatoes	1-3/4	0	183
24. Rice	1	0	191
25. Rice	1	0	194
26. Hash brown potatoes	1	0	180
27. Hash brown potatoes	3/4	0	150
28. Hash brown potatoes	1	0	186
29. French fries	1	0	190
30. French fries	3/4	0	106

III. CONCLUSIONS

A. Turkey and dressing, and creamed peas and carrots need more study.

B. One minute seems to be minimum time required for 3-ounce vegetable portions, and two minutes for 6-ounce meat portions to reach 160 degrees at 1200 watts.

FURTHER TESTING OF CALCULATED TIMES FOR
HEATING FOOD PORTIONS IN MICROWAVE

p. 80, Book 8 March 8, 1973

I. MATERIALS AND PROCEDURE

A. MATERIALS:

1. Poly bags
2. Food samples
3. Thermometer

B. PROCEDURE:

1. Package appropriate weights of samples in poly bags. Freeze.
2. Vent bag before heating.
3. Heat sample in microwave for calculated length of time.
4. Note:

    a. Equilibrated temperature
    b. Presence of hot and cold spots

II. RESULTS

A. Tests performed in Litton 550 ASD 2990

B. Food samples were 6-oz each:
1. Beef chunks
2. Ham
3. Fried Chicken
4. Turkey with small amount of gravy

PRODUCT	BEGINNING TEMP (^{O}F)	FINAL TEMP (^{O}F)	DESIRED TEMP (^{O}F)	HOT & COLD SPOTS
Beef Chunk	0	136	160	yes
Pork (Ham)	0	130	160	Yes - Not critical
Pork (Ham)	0	128	160	Yes
Poultry (Turkey)	0	126	160	Yes -about 30^{O} variance
Poultry (Turkey)	0	126	160	Surface hotter than middle
Poultry (Chicken)	0	160	160	3 different temps for 3 different pieces
Poultry (Chicken)	0	160	160	3 different temps for 3 pieces

III. CONCLUSIONS

A. Hot and cold spots present.

B. Calculation of time required to reach 160 only partially satisfactory.

C. Ham and turkey were satisfactory products; exterior of chicken was soggy, interior satisfactory; Beef was unacceptable because underdone interior, tough exterior.

PREPARATION OF MEAL IN OVENS OF HIGH AND LOW POWER

p. 78, Book 8 March 8, 1973

I. MATERIALS AND PROCEDURE

A. MATERIALS:

1. Food samples
2. Microwave transparent packaging materials

B. PROCEDURE:

1. Package food portions and freeze.
2. Calculate time requirement for each food.
3. Heat meat portion in high powered oven and vegetable in low powered oven for the calculated time.
4. Note:
   a. Temperature change
   b. Presence of hot and cold spots
   c. Time requirements compared to those calculated
   d. effects of packaging

II. RESULTS

A. High powered oven - Litton 550 ASD 2990
Low powered oven - Sharp R6500A 20702879

B. Food Items:

1. Beef
2. Peas
3. Mashed Potatoes

C. Calculated items:

SHARP		LITTON	
FOOD	TIME	FOOD	TIME
Peas	2 min 46 sec	Beef	1 min 25 sec
Mixed Veg.	2 min 46 sec	Pork	1 min 18 sec
Potatoes	2 min 52 sec	Poultry	1 min 27.6 sec
		Peas	55.8 sec
		Potatoes	53.4 sec

D. Packaging Selected:

1. Sealright Tray in polyethylene bag
2. Sealright Tray with film lid
3. Styrene insert for Aladdin insulated tray

PRODUCT	BEGINNING TIME (^{O}F)	FINAL TEMP (^{O}F)	DESIRED TEMP (^{O}F)	HOT AND COLD SPOTS
Beef	0	130	160	Yes
Peas	0	160	160	Minimal
Potatoes	0	165	160	Minimal

III. CONCLUSIONS:

A. Actual time required for portion to reach 160^{O}F. compared favorably to calculated time for vegetables in the Sharp. However, the meat was rare, suggesting more time needed.

B. The packaging selected was satisfactory. The shape of the tray did not seem to affect the efficiency of heating in this test.

SIMULATED SERVICE OF WHOLE MEAL HEATING

ACCORDING TO CALCULATED TIMES

p. 89, Book 8 April 9, 1973

I. <u>MATERIALS AND PROCEDURES</u>

A. MATERIALS:

1. Banquet T. V. Dinner
2. Sealright Tray
3. Oven Chinet Trays
4. Heat seal oven film

B. PROCEDURE:

1. Separate dinner into chunks.
2. Place chunks into selected trays, leaving entree portion uncovered, and putting heat seal lids on vegetable portions.
3. Heat for indicated length of time.
4. Note:
   a. Condition of foods, especially edges.
   b. Condition of packaging materials with different foods.

II. <u>RESULTS</u>

A. Trial A -

Ice still present in turkey, potatoes still cold. Thin edges of gravy dried and charred. Total time required to cook to required temperature was 3 minutes. Butter in mashed potatoes melted a hole in the Sealright PE.

B. Trial B -

Using turkey and dressing, mashed potatoes, peas and carrots packaged in Oven Chinet, heat for 2 minutes in Litton ASD 2990.

Food was cold, ice present in turkey and potatoes. Edges were satisfactory with no drying or charring. Board soft but not soggy with turkey and gravy and vegetables, best with mashed potatoes.

C. Trial C -

Turkey, dressing, mashed potatoes, peas and carrots packaged in Oven Chinet were heated separately in Litton 550 ASD 2990 for calculated length of time, with tops covered with styrofoam.

Food had cold spots, ice present in potatoes. Styrofoam did not prevent condensation, but kept moisture from dripping into food. Board softened somewhat.

III. CONCLUSIONS

A. Time calculations need re-evaluation.

B. Products need individual heating.

C. Drying and charring on edges is problem only when product is in relatively thin layers.

D. Oven Chinet satisfactory except in presence of high moisture. 3M Heat-Seal film makes a good seal and a conveniently peelable lid.

ENERGY TRANSFER WHEN ONE PORTION OUT OF
SEVERAL HEATED SIMULTANEOUSLY IS SHIELDED

p. 104, Book 8 May 8, 1973

I. MATERIALS AND PROCEDURE

A. MATERIALS:

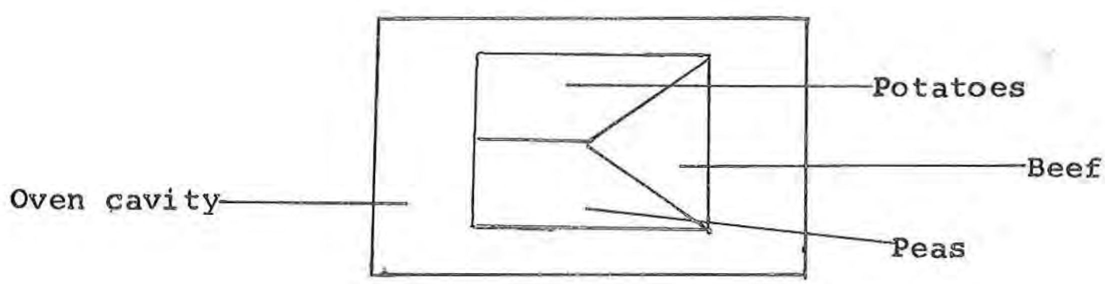
1. T. V. Dinners
2. 3-compartment paper plates
3. Aluminum foil
4. Insulator
5. Thermometer

B. PROCEDURE:

1. Transfer frozen chunks of dinners from aluminum tray to paper plate.
2. Heat 3-portion meal for selected length of time.
3. Allow to equilibrate for 5 minutes in insulator. Note temperature of each portion.
4. Wrap one portion in aluminum foil. Repeat steps 1-3.
5. Repeat, wrapping succeeding portions in foil.
6. Note temperature differences.

II. RESULTS

Following tests were performed in Litton 550 ASD 2990 for 2 minutes using Banquet Salisbury Steak Dinners and Chinet Paper trays. The food was placed in cavity according to the diagram below.



II. CONTINUED - ENERGY TRANSFER WHEN ONE PORTION OUT OF SEVERAL HEATED SIMULTANEOUSLY IS SHIELDED

TEST	PORTION SHIELDED	TEMPERATURE (°F.)			TOTAL
		MEAT	POTATO	PEA	
A	None	111	72 (ice present)	88	271
B	Potatoes (Incomplete shielding)	142	85 (ice present	160	
C	Peas	130	128	30 (ice present)	296
D	Meat	Too solid to insert thermometer	138	170	308
E	Potatoes	110	Too solid to insert thermometer	155	265
F	Peas	104	100	28 (ice present)	232
G	Meat	Too solid to insert thermometer	150	178	328

III. CONCLUSIONS

A. Microwave reflective nature of aluminum foil prevents heating of shielded food item.

B. The food portions not shielded reach a higher temperature than the same portions in a meal that is not shielded. This may indicate absorption by unshielded portions of heat not used by the shielded portions.

INVESTIGATING QUALITY OF SELECTED MEATS, VEGETABLES AND STARCHES WHEN COOKED WITH MICROWAVE ALONE

p. 39, Book 8 January 26, 1973

I. MATERIALS AND PROCEDURE

A. MATERIALS:

1. Plastic food trays
2. Food samples
3. Thermometer
4. Mylar film

B. PROCEDURE:

1. Place two samples of each food in plastic trays. Cover one with Mylar film.
2. Heat each sample for specified period of time in microwave.
3. Check samples for internal temperature (taken at deepest part of sample), surface and interior texture, tenderness, and color. Texture is judged in terms of dry, moist, soggy; color in terms of pale to dark.

II. RESULTS

A. Meats - 6-ounces each:

1. Samples included ground beef, fried chicken, chopped sirloin steak.
2. Ground beef hand formed into patties approximately 1-inch deep and 4-inches in diameter.
3. Quality of ground used had high fat content.
4. Ground was heated in Sharp R6500A 20702879, fried chicken and chopped sirloin heated both in the Sharp and Litton 550 151-3.

PRODUCT	OVEN	TIME	BEGINNING TEMP (°F)	FINAL TEMP (°F)	TEXTURE	TENDERNESS	COLOR
Ground Beef	Sharp	1 min	47	117	Soggy surface Mottled inter.	Tender (not done)	Red surface mottled inter.
Ground Beef	Sharp	2 min	47	178	Moist surface Moist interior	Very firm	Gray surface gray inter.
Ground Beef	Sharp	2½ min	46	177	Moist surface Moist interior	Very firm	Gray surface gray inter.
Ground Beef	Sharp	1½ min	45	150	Moist surface Moist interior	Tender	Mottled surface & inter.
Fried Chicken	Litton	2 min	0	190	Dry hard surface Tough interior	Tough	Poor
Fried Chicken	Litton	1½ min	0	200+	Dry hard surface Dry interior	Tough	No browning
Fried Chicken	Sharp	2 min	0	177	Dry surface Moist interior	Tough	Fair
Fried Chicken	Sharp	1½ min	0	40 (breast) 175 (drum)	Not hard but not crisp, moist interior		Fair
Chopped Sirloin	Litton	2 min	0	175	Tough	Tough	Poor
Chopped Sirloin	Litton	1½ min	0	130	Not as tough		Gray with lg red spot in center
Chopped Sirloin	Sharp	2 min	0	70	Mottled exter. Raw interior	Tough spots	Mottled with lg red spots
Chopped Sirloin	Sharp	3 min	0	100	Poor	Tough	Poor w lg. red spot

B. VEGETABLES

1. Items evaluated - 3-ounces each
   a. Green beans
   b. Broccoli
   c. Creamed peas and carrots

2. Samples heated for 15 seconds, then allowed to rest 15 seconds to thaw, then heated for specified length of time.

3. Samples heated in Litton 550-3 and Sharp R6500A 20702879

	PRODUCT	OVEN	TIME (MIN)	BEGINNING TEMP (°F)	FINAL TEMP (°F)	TEXTURE	COLOR
1.	Green Beans	Litton	1 min	0	155	Dry, tough	Good
2.	Green Beans (no thaw)	Litton	1 min	0	156	Not so dry. Almost tender-crisp	Good
3.	Green Beans (no thaw)	Litton	1½ min	0	142	Tender-crisp	Good
4.	Broccoli (no thaw)	Litton	1½ min	0	163	Tough	Good
5.	Broccoli	Litton	1½ min	0	154	Tender-crisp but dry	Good
6.	Peas & Carrots	Litton	1 min	0	80	Good but carrots overdone	Good

PRODUCT	OVEN	TIME (MIN)	BEGINNING TEMP ($^{\circ}F$)	FINAL TEMP ($^{\circ}F$)	TEXTURE	COLOR
7. Peas & Carrots	Litton	1 min	0	130	Odd (cream sauce broke down)	Good
8. Green Beans (no thaw)	Sharp	1½ min	0	160	Tender-crisp	Good
9. Broccoli	Sharp	1½ min	0	165	Tough-undercooked	Good
10. Broccoli (30 sec thaw)	Sharp	1½ min	0	165	Almost tender-crisp a bit tough	Good
11. Peas & Carrots (30 sec thaw)	Sharp	1 min	0	45	Cream sauce broke down	Good
12. Peas & Carrots (30 sec. thaw)	Sharp	2 min	0	95	Cream sauce broke down Slightly dry	Good

C. POTATOES

1. Items evaluated - 3-ounces each:

   a. Canned new potatoes (drained)
   b. Frozen crinkle cut French fries
   c. Frozen "Tator Tots"
   d. Frozen stuffed

2. Samples heated for thirty seconds, then allowed to rest thirty seconds to thaw, then heated for specified length of time.

3. Samples heated in Litton 550 151-3 and Sharp R6500A 20702879

	PRODUCT	OVEN	TIME (Min)	BEGINNING TEMP (°F)	FINAL TEMP (°F)	TEXTURE	COLOR
1.	Crinkle Cuts	Litton	2 min	0	170	Dry surface Dry & soggy interior	No browning
2.	Crinkle Cuts	Litton	1 min	0	170	Moist surface Soggy interiors	Pale - no browning
3.	Tator Tots	Litton	1 min	0	180	Moist - tender soggy spots	Brown
4.	Tator Tots	Litton	1 min	0	160	Tough Dry exterior Dry interior	Golden brown
5.	Stuffed	Litton	1½ min	0	150	Dry exterior Soggy interior	Powdered Cheese failed to melt

	PRODUCT	OVEN	TIME (Min)	BEGINNING TEMP (^oF)	FINAL TEMP (^oF.)	TEXTURE	COLOR
6.	Stuffed	Litton	2 min	0	150	Dry exterior Fluffier interior	Fair
7.	Canned new whole	Litton	45 sec	0	185	Moist exterior Firm interior	Good
8.	Crinkle Cut	Sharp	4 min	0	150	Poor	Pale
9.	Crinkle Cut	Sharp	2 min	0	165	Soggy	Pale
10.	Tator Tots	Sharp	1½ min	0	185	Poor, moist	Golden brown
11.	Stuffed	Sharp	1½ min	0	118	Good, moist	Poor, pale
12.	Stuffed	Sharp	3 min	0	130	Good, moist	Poor

III. CONCLUSIONS:

A. MEATS:

1. Ground Beef

   a. Texture showed evidence of microwave pattern with portions of interior cooked and uncooked.

   b. Toughness was evident in cooked samples.

   c. This product would be unacceptable because of hot-cold spots and tough areas.

2. Fried Chicken

   a. Lack of color development not such a problem because color already in product.

   b. Texture not crisp.

   c. Evidence of hot spots and tough areas.

B. VEGETABLES:

1. Vegetables generally more satisfactory than meats when produced in microwave alone.

2. Flavor acceptable even if the other factors are not.

3. Separation of cream sauce in creamed peas and carrots may have been fault of product, not heating methods.

C. STARCH (POTATO PRODUCTS)

1. Main problems seemed to be dry surfaces and uneven heating.

2. Excess moisture was evident. This may be due to presence of frost in product but microwave alone could not dispel the moisture in the time required.

3. Fried products were completely unacceptable due to poor color and toughness.

SHIELDING TO PROTECT EDGES

p. 92, Book 8 April 10, 1973

I. MATERIALS AND PROCEDURE

A. MATERIALS:

1. Two identical melamine trays
2. Aluminum foil
3. Foam insulator
4. Thermometer
5. Food Samples of a liquid nature

B. PROCEDURE:

1. Place band of foil around side of one tray, extending ¼ inch below bottom of tray.

2. Place Samples in tray.

3. Heat for selected length of time.

4. Let samples equilibrate for five minutes in foam insulator.

5. Note temperature and condition of edges.

II. RESULTS

The following test was made in Litton 550 ASD 2990 using Banquet's Cook-in-Bag Salisbury Steak with Gravy, frozen, and heated for one minute and twenty-five seconds. The condition of the edges was about the same for both samples; very little edge drying. The temperature after five minutes was 74°F. in the unshielded tray and 52°F. in the shielded tray.

III. CONCLUSIONS

A. The aluminum reflects the microwaves which results in slower heating.

B. Other factors beside microwave reflectiveness must operate in edge drying.

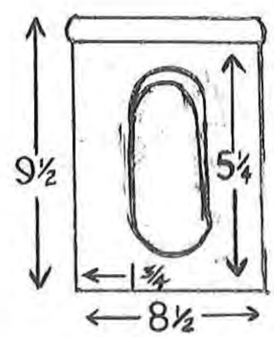
USE OF SHIELDING IN HEATING TROUT ALMONDINE

p. 108, Book 8 May 9, 1973

I. MATERIALS AND PROCEDURE

A. MATERIALS:

1. Ten Trout Almondine (O'Brian-Spotorno) thawed (contained in melamine trays)
2. Foil bag with identical windows as sketched.



B. PROCEDURE:

1. Heat one trout without bag.
2. Heat remaining nine in bag.
3. Insert tray in bag so that center of trout is exposed and edges of fish and sauce are covered by foil.
4. Note condition of edges.

II. RESULTS

Trout without shielding showed marked drying and browning at edges of sauce. The shielded fish showed slight browning at edges, with four showing no browning.

III. CONCLUSIONS

The microwave reflection of the aluminum seemed to protect the thin edges of the fish and sauce from overbrowning, while heat conduction from the center of the fish heated the edges.

SHIELDING TO PROTECT EDGES

P. 92, Book 8 April 10, 1973

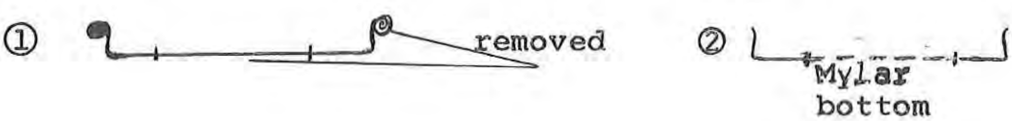
I. MATERIALS AND PROCEDURE

A. MATERIALS:

1. Reynolds aluminum tray #1060-45-V
2. Mylar oven film
3. Food samples that are fairly liquid or have gravy.
4. Melamine tray

B. PROCEDURE:

1. Modify aluminum tray according to sketch below using Mylar to make bottom.
2. Place selected weight of food sample in tray and identical food sample in melamine tray.
3. Heat in microwave selected length of time, heating samples separately.
4. Note condition of edges of food samples.



II. RESULTS

This test was performed in Litton 550 ASD 2990 using Banquet's Cook-in-Bag Salisbury Steak with Gravy removed from the bag, frozen and heated for 1 minute 25 seconds. The sample in the melamine tray dried at edges; the sample in aluminum remained liquid throughout.

III. CONCLUSION

The microwave reflective quality of the aluminum may have protected the thin edges of the food enough to keep them moist.

HEAT RESISTANCY OF CERTAIN PLASTICS

p. 81 Book 8 March 15, 1973

I. MATERIALS AND PROCEDURE

A. MATERIALS:

1. Samples of:
   Polyterephthalate (polyester) (3-M Co.)
   Lexan (General Electric Co.)
   Polysulfone (2½ mils) (Union Carbide & Carbon Co)

2. Aluminum tart pans

3. Ruler

B. PROCEDURE:

1. Cut three inch round from each sample.
2. Staple to rim of tart pan.
3. Heat for one minute at 400^{o}F.
4. Note depth of sag.

II. RESULTS

A. Polyterephthalate sagged 7/8-inch.

B. Lexan sagged 5/8-inch - thermoformed.

C. Polysulfone sagged 5/8-inch - thermoformed.

PERFORMANCE OF VALOX HIGH TEMPERATURE RESIN
AT CRISPING TEMPERATURES

p. 11 Book 8 December 2, 1972

I. MATERIALS AND PROCEDURE

A. MATERIALS:

1. Sample dies of Valox 310 (unreinforced) and Valox (reinforced) four-inches in diameter and 1/8-inch thick.

B. PROCEDURE:

Dies were heated at 400°F. in the Food Finisher 201-1002 for the same length of time.

II. RESULTS

Valox 310 maintained its shape but deflected and dented easily. The Valox was quite firm and did not deflect easily. Some aldehyde-type odor was apparent after a few minutes heating.

PERFORMANCE OF POLYSULFONE AT CRISPING TEMPERATURES

p. 101 May 3, 1973

I. MATERIALS AND PROCEDURE

A. MATERIALS:

1. Polysulfone Trays
2. Food samples

B. PROCEDURE:

1. Place food samples in trays.
2. Heat in Crisper at selected temperature for selected length of time.
3. Note condition of tray.

II. RESULTS

A. Biscuits at 450°F. Tray deformed badly in less than two minutes.

B. Fried chicken at 400°F. Moderate deformation.

C. Pizza rolls at 375°F. Very slight deformation of tray bottom.

PERFORMANCE OF OVEN CHINET IN MICROWAVE AND CRISPER

p. 88, 89, 90, 100, 102

April 3, 9, 30,
May 4, 14, 1973

I. MATERIALS AND PROCEDURE

A. MATERIALS:

1. Oven Chinet Trays
2. Food Samples
3. Scotch heat-seal film for use with Chinet

B. PROCEDURE:

1. Place selected weights of samples in trays. Seal. Freeze.
2. Expose some samples to microwave for selected length of time. Expose other samples to Jet-Crisping for selected length of time.
3. Note condition of board.

II. RESULTS

A. Six-ounces fried chicken was heated to two minutes of microwave in the Litton 550 ASD 2990. Some soaking of the board was evident, although not severe enough to become soggy or leak. Rather rapid moisture transfer through the board was noted.

B. Three-ounces green peas and three-ounces mashed potatoes were heated from one minute fifteen seconds in the Litton 550 ASD 2990. The food samples were slightly dehydrated after heating.

C. Three-ounces new potatoes with liquid were heated for fifty-five seconds in the Litton 550 ASD 2990. Interior bottom soggy and exterior bottom damp in spots, although bottom did not collapse or leak. Seal removal excellent and neat.

D. Three-ounces new potatoes with liquid heated for sixty-five seconds. Board very soggy, with moisture collecting under tray on oven shelf, but did not leak or collapse.

E. Three-ounces green beans in butter sauce in Litton 550 ASD 2990. Board softened but did not get soggy.

F. Oven Chinet stands 450°F. in double Crisper with slight browning; 400°F. with less browning

III. CONCLUSIONS

A. Oven Chinet shows a tendency to absorb oil and grease.

B. Oven Chinet tends to become soft and soggy in steam heat conditions, although does not leak or collapse.

C. Rapid transfer of moisture through board may have implications for food quality in microwave.

D. High temperature finish is effective at browning and crisping temperatures.

E. The heat-seal lid removal is neat and easy.

PERFORMANCE OF COATINGS APPLIED TO BOX BOARD

p. 93 Book 8 April 18, 1973

I. MATERIALS AND PROCEDURE

A. MATERIALS:

1. Polyethylene coated board (trays and lids made by International Paper Company).
2. Polypropylene coated board (trays made by Sprinter, obtained through Potlatch Forest, Inc)
3. Food samples (in this case biscuits and hamburger patties with gravy)
4. Thermometer.

B. PROCEDURE:

1. **Start test at 200^{o}F. in Crisper (Dav-Mor Prototype used for this determination); Move temperature up in increments of 50^{o}F. for each test.**
2. **Place sample in tray. Test at each temperature with both dry and liquid contents, using biscuits for dry contents and beef with gravy for liquid contents.**
3. **Expose to microwave for period of time appropriate for the sample. Expose to Crisper for selected length of time.**
4. **Note:**
   a. **Temperature of food next to board at side of tray.**
   b. **Condition of board**
   c. **Condition of seals**

II. RESULTS

A. Polyethylene Coated Board

	CONTENTS	TEMP. (^{O}F.) OF CRISPER	TIME (Min) IN CRISPER	TEMP. (^{O}F.) OF FOOD	CONDITION OF SEALS & BOARD
#1	Biscuits	200	1	150	Unchanged
#2	Biscuits	200	2	155	Unchanged
#3	Beef/gravy	200	1	140	Unchanged
#4	Beef/gravy	200	3	140	Unchanged
#5	Biscuits	250	1	155	Polyethylene just beginning to soften. Seals holding.
#6	Biscuits	250	2	170	Same as #5. Seals holding.
#7	Beef/gravy	250	1	156	Polyethylene softened but not evident below liquid line, seals holding.
#8	Beef/gravy	250	2		Same As #7
#9	Biscuits	300	1	182	Softening more pronounced than at previous temps; seals holding.
#10	Biscuits	300	2	185	Bubbling evident. Seals evident.
#11	Beef/gravy	300	1	144	Bubbling evident but not below liquid line. Seals holding.
#12	Beef/gravy	300	2	145	Bubbling evident, extending below liquid line on one side. Seals holding.

	CONTENTS	TEMP. (^{O}F.) OF CRISPER	TIME (min) IN CRISPER	TEMP. (^{O}F.) OF FOOD	CONDITION OF SEALS & BOARD
#13	Biscuits	350	1	185	Bubbling and flowing evident, melting to Mylar lining. Seals holding.
#14	Biscuits	350	2	180	Same as #13
#15	Beef/gravy	350	1	140	Bubbling, flowing evident; none below liquid line; seals holding.
#16	Beef/gravy	350	2	166	Bubbling extended below liquid line on all sides; seals holding.
#17	Biscuits	400	1	190	Color darkened, bubbling not as pronounced. Seals released.
#18	Biscuits	400	2	190	Color darkening. More pronounced, bubbling barely evident. Flowing more pronounced. Seals released.
#19	Beef/gravy	400	1	115	Slight color change. Bubbling evident above and below liquid line; seals holding.
#20	Beef/gravy	400	2	170	Color darkened, Bubbling not evident. Seals released.
#21	Biscuits	450	1	180	Color darkened more. Bubbling very scarce; seals released.
#22	Biscuits	450	2		Boards scorched; all seals released.

B. Polypropylene Coated Board (Test only at 350-400°F. for two minutes.

	CONTENTS	TEMP. (°F.) OF CRISPER	TIME (Min) IN CRISPER	CONDITION OF SEALS AND BOARD
#1	Biscuits	350	2	Softening of Polypropylene evident but not extreme. Slight color change, distortion of tray bottom; seals holding
#2	Beef/gravy	350	2 (not sure of time)	Color change around edges, seals loosened but held liquid. Slight evidence of softening.
#3	Biscuits	400	2	Some flow, some color change; seals holding. Bottom warping.
#4	Beef/gravy	400	2	Corner seals released but held liquid; pronounced color change, Softening and oil soaking evident.

III. **CONCLUSIONS**

A. Liquid contents have the effect of cooling the board with which it is in contact, producing the effect of less heat on the board than dry contents at the same temperature.

B, Polyethylene amd Polypropylene coated board do not react satisfactorily at temperatures of 350°F. and above.

C. Leakproof corners made by heat sealing this board do not remain leakproof at temperatures of 350°F. and above.

TESTING OF MATERIALS FOR CRISPER INSERTS

p. 86 Book 8 March 26, 1973

I. MATERIALS AND PROCEDURE

A. MATERIALS:

1. Melamine trays
2. Aluminum trays
3. Nylon net of various weights and mesh sizes
4. Food samples

B. PROCEDURE:

1. Place food sample in tray to be tested.
2. Cover with the material or materials to be tested.
3. Heat in crisper at time and temperature required for product.
4. Note behavior and condition of tray and cover.

II. RESULTS

The following tests were performed in the Prototype Crisper (Associated Food Equipment Company) at 400°F. for 1½-minutes, using frozen fried chicken.

A. Melamine covered with unsupported PVCD film (Saran) - Saran almost completely disappeared, however, melted on two out of three pieces of chicken; melamine was unaffected.

B. Melamine covered with Saran supported by wide mesh nylon netting - Saran fell away, none remaining on chicken, mesh developed slight odor and browned slightly; tray unaffected.

C. Aluminum tray covered with cardboard lid with cut-out center filled with Saran - Saran disappeared, but dripped into tray, slight amount on chicken.

D. Aluminum tray covered with heavy nylon mesh (Jay-Tan Cleaning pad) (no food load) - very little or no effect on mesh, put off fishy odor.

E. Aluminum tray covered with lightweight (dress weight) nylon net (no food load) - no effect on net.

F. Aluminum tray covered with Saran supported by light weight nylon net - Saran fell away, chicken browned.

G. Aluminum tray covered with Saran supported by light weight nylon net containing biscuits pre-cooked in microwave - Saran fell away supported by net, biscuits browned satisfactorily.

H. Aluminum tray covered with Teflon wire screen containing biscuits pre-cooked in microwave-teflon shrunk, ending test.

III. CONCLUSIONS

A. A shrink film requires a support to shrink over or it drips into product under these conditions.

B. Light weight nylon net makes a satisfactory support for shrink film. These conditions have little effect on it.

C. Melamine is a satisfactory material for Crisper use.

D. Browning and crisping occur satisfactorily through mesh.

TEST OF EFFECTIVENESS AS SEAL OF HOT-MELT GLUE WITH POLYETHYLENE TRAYS

p. 85 Book 8 March 23, 1973

I. MATERIALS AND PROCEDURE

A. MATERIALS:

1. HDPE Trays
2. Glue Gun
3. Hot-melt glue
4. Film for covers
5. Food Samples

B. PROCEDURE:

1. Place appropriate amount of sample in tray.
2. Seal with film, attaching to tray with hot-melt glue.
3. Freeze.
4. Heat in microwave.
5. Note condition of seal in freezing and heating, ease of removal.

II. RESULTS AND CONCLUSIONS

Package was prepared using Sealright HDPE trays and Montgomery Ward's all purpose Hot-melt glue with Montgomery Ward glue gun 32478-84.9-510. Green Peas, green beans in butter sauce, and mashed potatoes were the foods used.

Hot-melt glue seals weakened in freezing and regained strength with heating, thus allowing package to open in storage and making opening of package difficult.

PERFORMANCE OF SEALRIGHT TRAY IN

POLYETHYLENE BAG IN MICROWAVE

p. 99 Book 8 April 27, 1973

I. MATERIALS AND PROCEDURE

A. MATERIALS:

1. Sealright Tray
2. Polyethylene Bag
3. Food Samples

B. PROCEDURE:

1. Place appropriate sample in tray. (In this case, six-ounces roast beef with gravy) Place in polyethylene bag, heat seal, freeze.
2. Expose sample to microwave for selected length of time. (In this case, two minutes)
3. Note conditions of tray, bag and seal.

II. RESULTS

Bag stuck to tray after contact with steam heat, and melted where contact was made with gravy. Tray softened in heat and deformed with handling.

III. CONCLUSIONS

Sealright tray contained in polyethylene bag very unsatisfactory for this system.

PERFORMANCE OF DIAMOND DELUXE PULPBOARD IN MICROWAVE

p. 79 Book 8 March 8, 1973

I. MATERIALS AND PROCEDURE

A. MATERIALS:

1. Three item T.V. Dinner (ham with raisin sauce and sweet potatoes, green peas and stewed apples used in this determination.)
2. Diamond Deluxe dinner plate

B. PROCEDURE:

1. Separate dinner into components while still frozen.
2. Place items on dinner plate.
3. Heat for three minutes in microwave.
4. Note condition of board.

II. RESULTS

Plate became very soggy.

III. CONCLUSION

Diamond Deluxe board is unacceptable when used in microwave with foods of high moisture content.

EFFECTS OF OIL AND GREASE ON POLYETHYLENE COATED BOARD IN MEAL-EZE TRAYS (International Paper Company)

p. 98 Book 8 April 24, 1973

I. MATERIALS AND PROCEDURE

A. MATERIALS:

1. Meal-Eze Trays and lids made of polyethylene coated board.
2. Samples of grease or oil bearing food (In this case, fried chicken)

B. PROCEDURE:

1. Measure selected weight of chicken into tray. Seal. Freeze.
2. Expose to microwave for selected length of time.
3. Note condition of board.

II. RESULTS

Oil soaking was noticeable in the corners.

III. CONCLUSION

Cut edges or exposed places in coated board are subject to wicking and oil soaking.

PERFORMANCE OF TRAY-TITE POLYPROPYLENE COATED BOARD

p. 88 Book 8 April 3 & 9, 1973

I. MATERIALS AND PROCEDURE

A. MATERIALS:

1. Tray-Tite trays made of polypropylene coated board
2. Food samples (Frozen green beans with butter sauce, frozen green peas)
3. Tray-Tite heat seal lids.

B. PROCEDURE:

1. Place appropriate amounts of samples in trays to be tested.
2. Apply lids.
3. Freeze.
4. Heat in microwave for specified length of time.
5. Note condition of board, seal and food.

II. RESULTS

1. Tray-Tite with green beans heated for 52 seconds. Beans, in good condition; board, in excellent condition. Seal, too good-hard to remove, resulting in torn tray and unacceptable appearance.

2. Tray-Tite with frozen peas heated for 52 seconds. Peas heated; board, in excellent condition; seal, difficult to remove, resulting in torn tray and unacceptable appearance.

III. CONCLUSION

Tray constructed in the Tray-Tite pattern of polypropylene coated board performs well in frozen storage and under microwave and steam conditions. The heat seal lid is difficult to remove causing an unacceptable appearance and difficulty in handling. This difficulty and appearance problem makes this tray configuration unsuitable for use in this device.

TEST FOR EFFICIENCY OF HEATING RELATED

TO PACKAGE AND SHAPE OF FOOD

p. 79 Book 8 March 8, 1973

I. MATERIALS AND PROCEDURE

A. MATERIALS:

1. Food samples
2. Polyethylene bags
3. Food trays

B. PROCEDURE:

1. Prepare appropriate weight of food in configuration desired in tray.
2. Seal in polyethylene bag. Freeze.
3. Heat for selected time in microwave with bag in place.
4. Note condition of food.

II. RESULTS

A. Green peas were packed in a layer in a Sealright tray. Microwave heating produced a steam effect that resulted in a satisfactory product. Tray satisfactory.

B. Mashed potatoes mounded into a styrene Aladdin tray. Mound flattened somewhat during heating, but maintained an acceptable shape. Tray softened noticeably.

III. CONCLUSIONS

A. Aladdin styrene trays not suitable for steam environment.

B. Sealright PE trays acceptable for steam environment.

C. Steam produced in closed vented package effective for cooking vegetables.

FLIP-FLOP METHOD OF PACKAGING AND SERVING

p. 108 Book 8 May 16-18, 1973

I. MATERIALS AND PROCEDURE

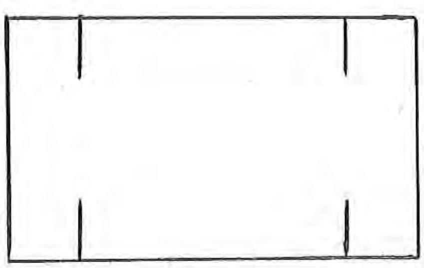
A. MATERIALS:

1. Box board
2. Oven proof plastic film for liners
3. Board breaking tools
4. Scissors
5. Means of securing corners (staples, Scotch Magic tape)
6. Food samples

B. PROCEDURE:

1. Make telescoping boxes of appropriate size.
2. Line.
3. Fill with appropriate food samples. Freeze.
4. Heat and serve; inverting box either before heating or serving.
5. Note appearance of sample and ease of removal of lid.

Box Pattern:



Outside Dimensions:
5 x 8 x 1¼ inches

Box Top:
10½ x 7½ inches with 1¼-inch slashes

Box Bottom:
10-3/8 x 7-3/8 inches with 1¼-inch slashes

II. RESULTS - Litton 550 ASD 2990 for two minutes.

A. Beef with gravy packed and stored in top and inverted into liner in box bottom for heating and serving. Heated. No leakage, liquid fill to bottom of tray as warmed, leaving the top dry. Lid easily removed.

B. Turkey, dressing and gravy packed and stored in bottom, and inverted into liner of top for heating and serving. Good appearance; some liquid remained on top with minimum in bottom of tray. No leakage; lid glued to trays with gravy making removal difficult.

C. Beef with gravy packed and stored in bottom, and inverted into top liner for heating and serving. Most of liquid fell to bottom leaving top dry; lid stuck to tray. Very difficult to remove.

D. Turkey, dressing; gravy packed and stored in top, and inverted into bottom liner for heating and serving. Minimum liquid in bottom of tray; some remaining on top; no leakage; lid easily removed.

E. Turkey, dressing; gravy packed, stored and heated in top, and inverted into bottom to serve. Appearance altered because package fell in freezer. No leakage. Lid easily removed.

F. Turkey, dressing, gravy packed, stored and heated in bottom, inverted into top liner to serve. Good appearance; gravy stayed on top. No leakage; lid easily removed.

G. Beef with gravy, packed, stored, heated in top, inverted into bottom to serve. Appearance good; gravy on top; no excess liquid in bottom of tray; spattering during cooking and leakage upon inversion occurred.

H. Beef with gravy packed, stored, heated in top, inverted into bottom to serve. Appearance good, with gravy on top of product and no excess liquid in bottom of tray; no spattering while cooking; no leakage when inverted.

I. Beef with gravy packed, stored, heated in bottom and inverted into top to serve. Appearance good. Liners heat-sealed to box parts. No spattering or leakage occurred, lid easily removed.

J. Beef with gravy - Same as "I".

III. CONCLUSIONS

A. Packing and storing in top, inverting to heat and serve in bottom is convenient for uncovering as weight of portion holds bottom down as top is slipped off; however leakage occurs when inversion is done after heating.

B. Packing, storing and heating in bottom and inverting to serve in top produces best appearance and less leakage.

C. Telescoping box package is easily opened.

D. Liner heat-sealed to container makes more easily manipulated package.

TESTING FOR CRISPER PACKAGE

p. 110 Book 8 May 22, 1973

I. MATERIALS AND PROCEDURE

A. MATERIALS:

1. Trays
2. Liner material
3. PVCD film (Saran)
4. Nylon net
5. Food samples

B. PROCEDURE:

1. Prepare liner for trays (leaving some unlined).
2. Place appropriate food samples in each.
3. Heat for selected times at selected temperatures.
4. Note condition of food, trays, cover and liner.

II. RESULTS

These tests performed in Dav-Mor prototype Crisper using Oven Chinet trays, Heat-seal Scotch pack for lining, and fried chicken as food load.

A. Uncovered, lined tray heated for 5 minutes in Sharp R6500A and 2 minutes at 450°F. in Crisper - Liner shrank, Chinet browned and out-gassed, chicken overdone.

B. Covered, lined tray heated for 5 minutes in Sharp and 1½ minutes at 450°F. in Crisper - Chinet browned and out-gassed, liner shrank too badly to be acceptable. Browning seemed to occur through film cover, although film shrank so badly that this result is unreliable.

C. Unlined tray covered with Saran and nylon net heated in Sharp for 3 minutes and Crisper at 400°F. for 1½ minutes - Saran fell back over net and chicken crisped through net. Saran disappeared in microwave only.

III. Conclusions

A. Over Chinet with Saran and nylon net cover is satisfactory crisper package.

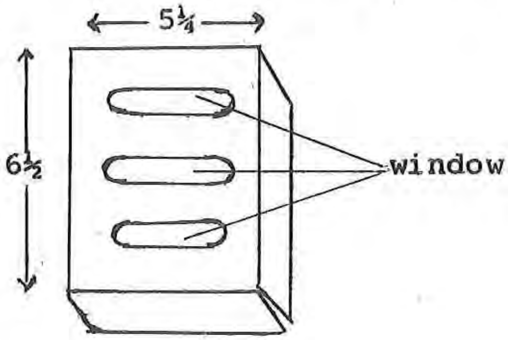
B. Heat-Seal Scotch Pak film is unsatisfactory as a liner.

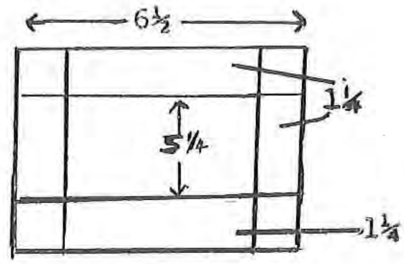
CONFIGURATION DESIGNS FOR CRISPER PACKAGE

p. 114 Book 8 June 8, 1973

DESIGN I

Box is one piece (lunch box type construction) with windows cut in lid. Tray fitting inside of box is either shrink wrapped or bagged. Wrap or bag disintegrates when in contact with heat allowing hot air to circulate around food. Box contains and hides melted plastic and protects oven.





Dimensions in inches.

RESULTS AND CONCLUSIONS

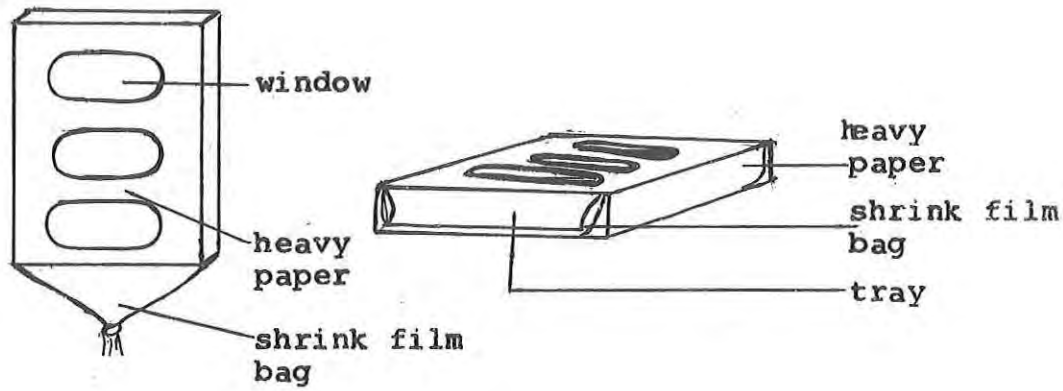
Design not desirable for following reasons:

1. Shrink film has no support on which to fall back.

2. Tray inside of box is not necessary as box can function as tray.

DESIGN II

Tray is covered by overwrap made of heavy paper and shrink film. Overwrap could be bag-like. Windows are cut where overwrap fits over top of tray to allow hot air circulation in crisping.

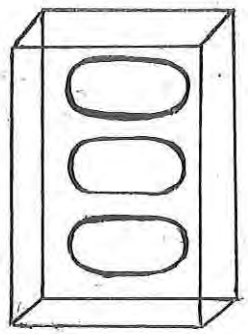


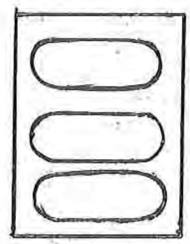
RESULTS AND CONCLUSIONS

1. Shrink film has no support on which to fall back.

DESIGN III

Tray is telescoping box with windows in lid. Lid has insert with window configuration like lid to support shrink film used to cover windows.





RESULTS

1. Heated Frozen fried chicken in this package for two minutes in Litton 550 ASD 2990, then in double crisper at 450°F. for two minutes - Saran shrank to strips of board in insert with some dripping into tray.

2. Shrink film was glued to board with Silastic adhesive and insert eliminated. The Silastic released with steam and heat making this a doubtful test. However, the film fell back to one strip that remained glued.

SIMULATION OF STACK METHOD OF STORAGE AND RETRIEVAL

p. 105 Book 8 May 11, 1973

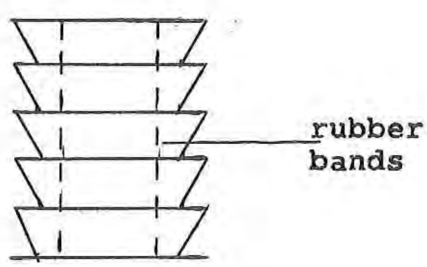
I. MATERIALS AND PROCEDURE

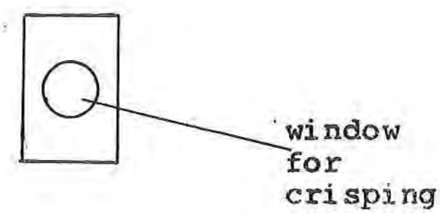
A. MATERIALS:

1. Trays and lids to be stacked.
2. Food samples
3. Staples and rubber bands.

B. PROCEDURE:

1. Fill trays with appropriate samples.
2. Cut hole from the lid approximately 1/4 to 1/3 the area of the lid.
3. Seal trays with prepared lids, stapling to tray to simulate an excellent seal.
4. Stack trays about eight high. Hold stack together with rubber bands to simulate spring loaded storage.
5. Hold at 0^{o}F. and test periodically for ease of sliding and condition of contents of top tray.





II. RESULTS

Test performed with Meal-Eze Trays and green peas; two stacks tested, started 4-19-73.

DATE	RESULT
5-11-73	One tray in one stack stuck, others moved easily. Peas in top tray beginning to dry.
6-26-73	Two trays stuck in one stack, other stack moved easily. Peas in top tray showing cracks in surface.
8 - 73	Both stacks stuck, but easily loosened.

SIMULATION OF DISPENSING METHODS

p. 82, Book 8 March 19, 1973

I. MATERIALS AND PROCEDURE

A. MATERIALS:

1. Containers for preparing inserts
2. Polyethylene bags
3. Food samples
4. Plates for receiving food

B. PROCEDURE:

1. Prepare inserts by cutting from container identical to receiving container.
2. Place appropriate amount of food into insert, seal in PE bag, freeze.
3. Place insert, in bag (vented), in microwave, heat.
4. Dispense into plate by removing top of bag, positioning insert in open bag over plate, and drawing bag backward pushing insert into plate.

PROCEDURE 2:

1. Place appropriate amount of sample in PE bag, seal, freeze.
2. Vent bag, heat in microwave.
3. Remove top of bag, dispense by positioning bag with open end over plate, mechanically pushing contents onto plate as bag is drawn backwards.

II. RESULTS AND CONCLUSIONS

A. Both methods worked satisfactorily using green peas.

B. Bag in Procedure 2 needs curved dispensing chute for best results, especially using an item such as mashed potatoes.

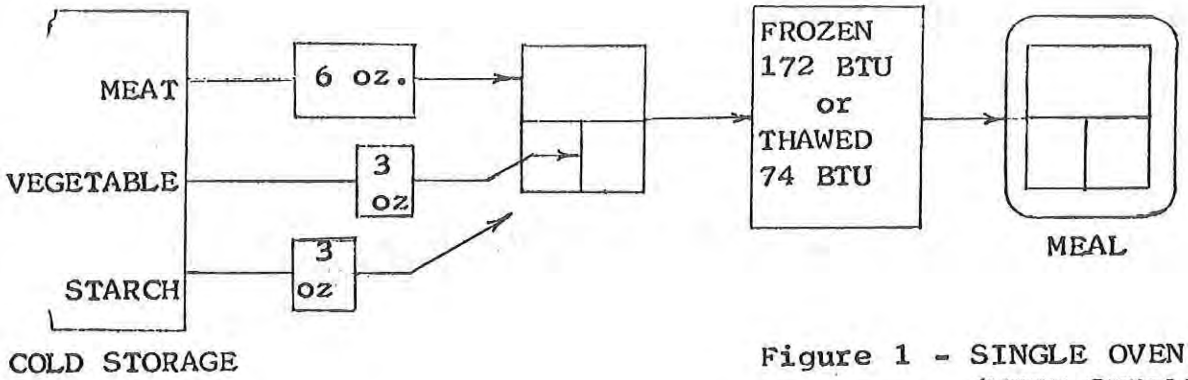


Figure 1 - SINGLE OVEN (WITH SHIELDING)

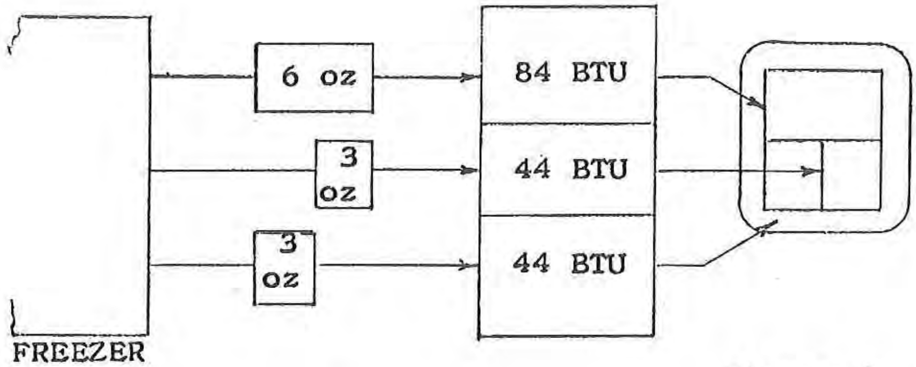


Figure 2 - THREE OVENS

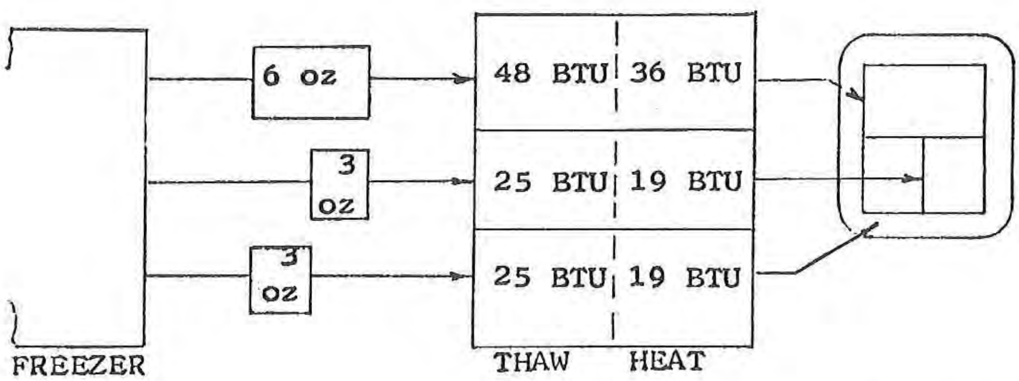


Figure 3 - THAW AND HEAT OVENS

SYSTEMS CONFIGURATION AND CALCULATED* HEAT INPUT

*Refrigeration Engineering Data (18)

VII B 4 HEATING TIMES ENERGY TO HEAT TO SERVING

PRODUCT	PORTION WEIGHT	INITIAL TEMP.	BTU REQ.	HEATING RATES			TIME CALCULATED		FINAL TEMPERATURE OBSERVED
				OVEN RATING		GRAPHED*	OVEN	OBSERVED	
				WATTS	BTU/MIN	BTU/MIN	RATING	RATING	
ROAST BEEF	5 oz	35°	27.67	650	37.14	18	.74 min	1.58 min	164°F.
ROAST BEEF	5 oz	0°	62.54	650	37.14	18	.32 min	3.55 min	175°F.
ROAST BEEF	5 oz	35°	27.67	1250	71.42	51.5	1.86 min	.53 min	150°F.
ROAST BEEF	5 oz	0°	62.54	1250	71.42	51.5	.82 min	1.24 min	166°F.
GREEN PEAS	3 oz	35°	17.03	650	37.14	15.0	.99 min	1.13 min	186°F.
GREEN PEAS	3 oz	0°	39.19	650	37.14	15.0	.43 min	2.67 min	190°F.
GREEN PEAS	3 oz	35°	17.03	1250	71.42	46.0	2.70 min	.37 sec	182°F.
GREEN PEAS	3 oz	0°	39.19	1250	71.42	46.0	1.17 min	.87 min	186°F.

*BTU input to water load equivalent to water content of food portion

APPENDIX C: EQUIPMENT REFERENCES

C-1. JET AIR OVEN WITH MICROWAVE HEATING

DONALD PAUL SMITH

SHEET 3 of 4

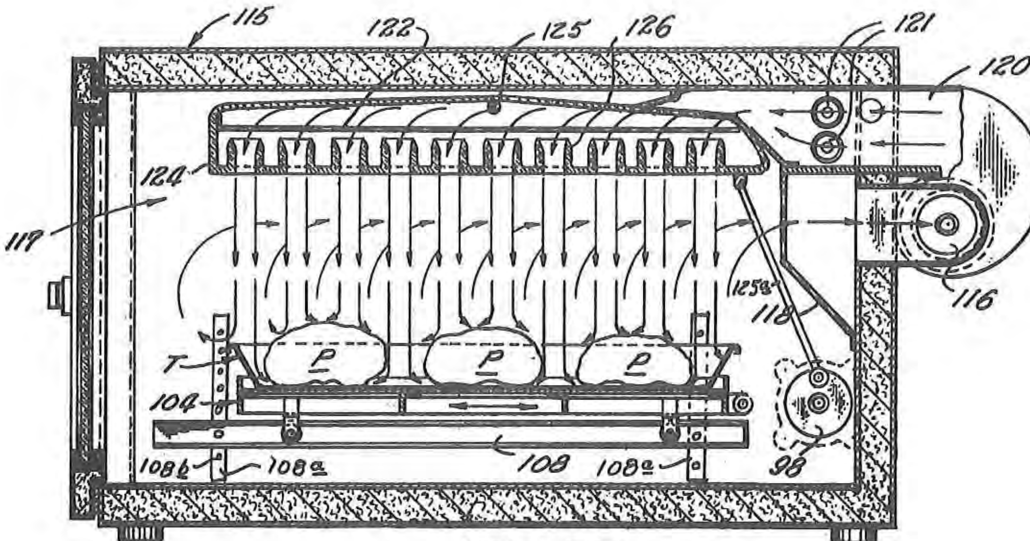


Fig. VII

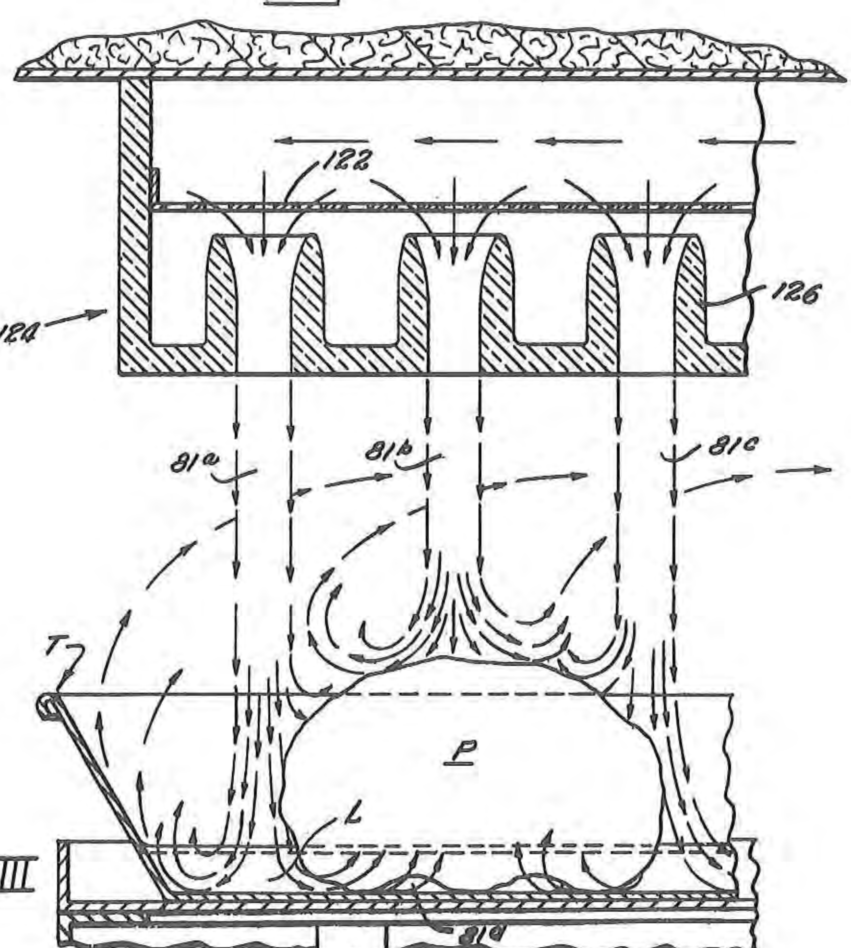


Fig. VIII

June 4, 1968 W. R. MURRAY ET AL 3,386,550

AUTOMATIC ELECTRONIC MICROWAVE COOKING AND VENDING MACHINE

Filed Nov. 15, 1966 8 Sheets-Sheet 3

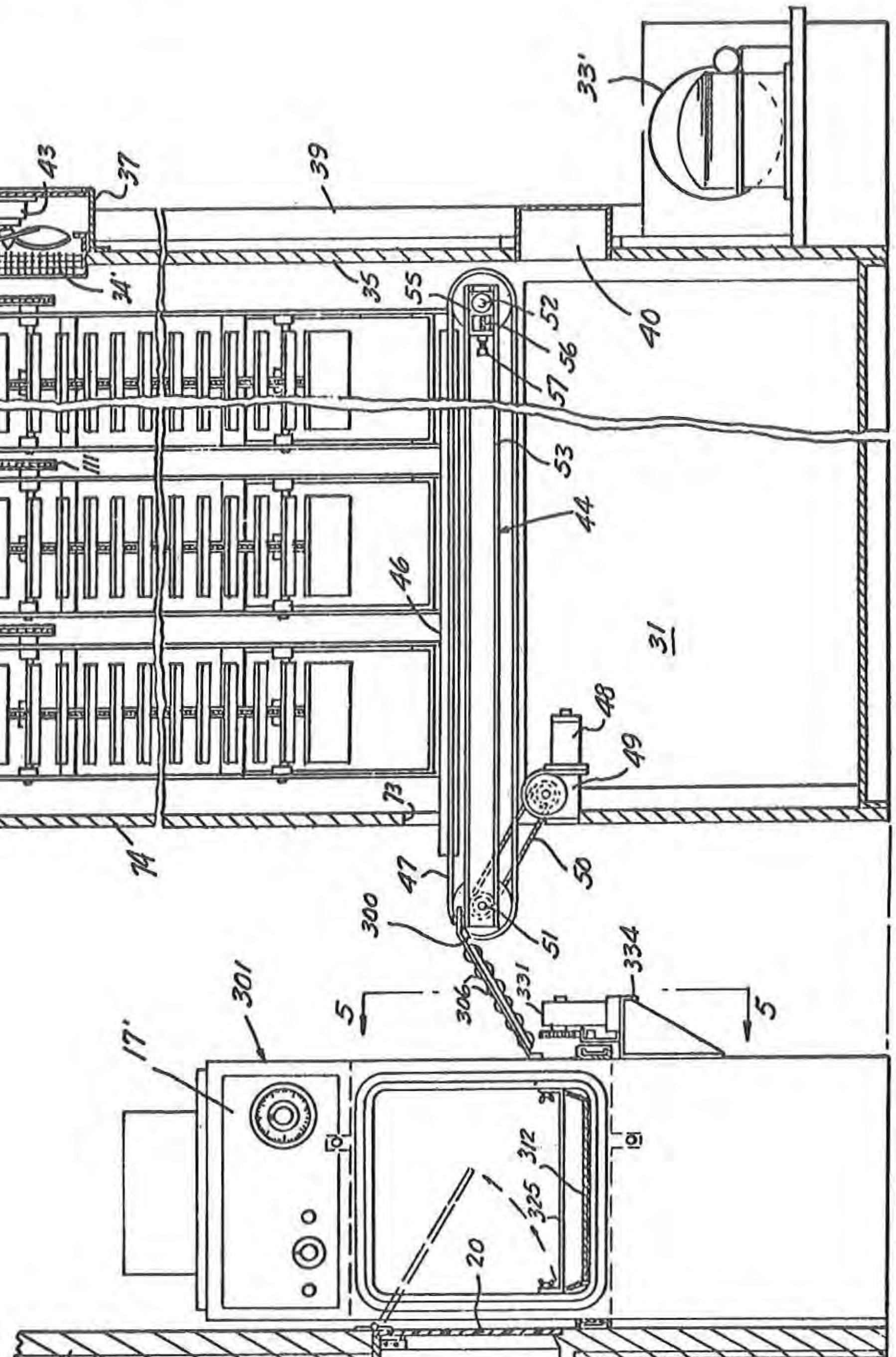
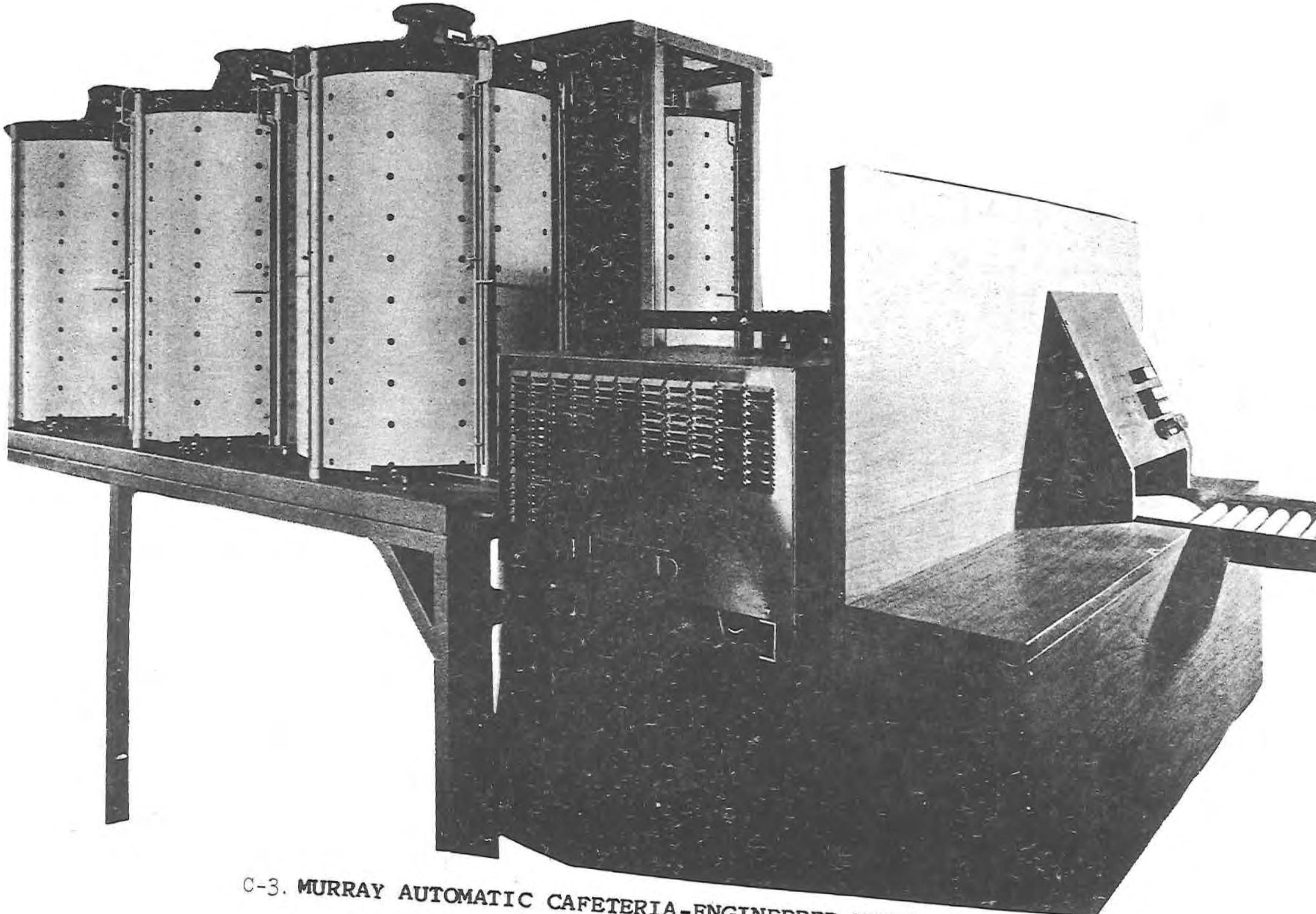


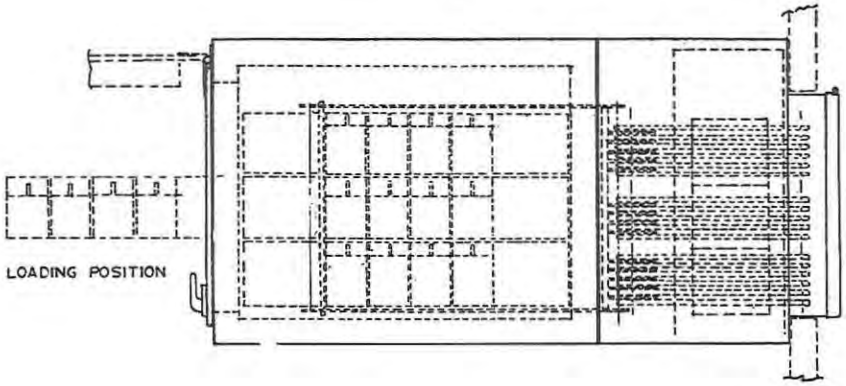
FIG. 4.

INVENTORS.
WILLIAM R. MURRAY,
WILLIAM O. MURRAY,
BY
Berman, Davidson & Berman
ATTORNEYS

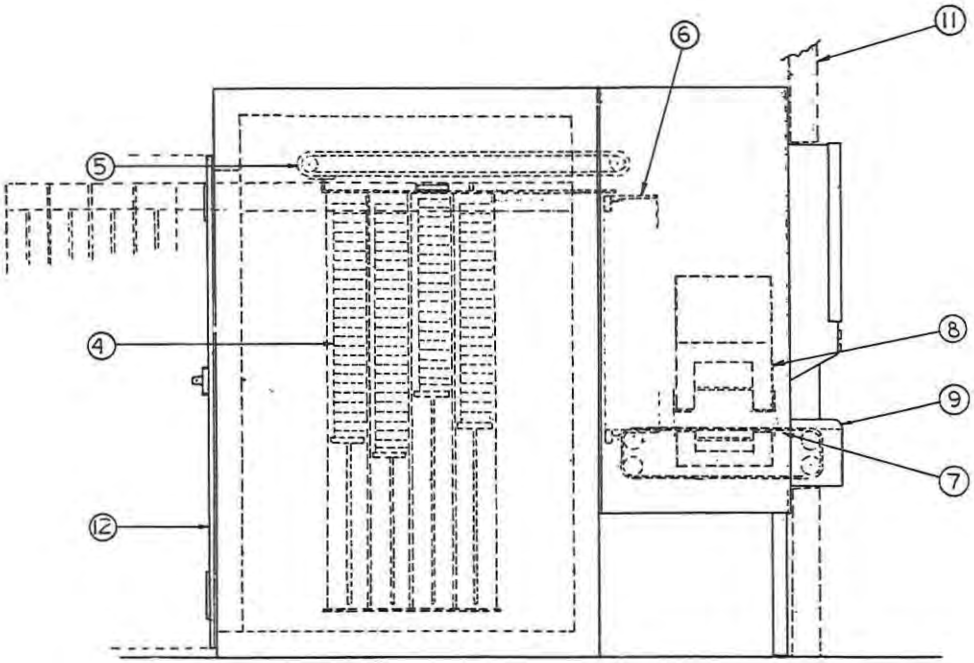


C-3. MURRAY AUTOMATIC CAFETERIA-ENGINEERED MODEL II

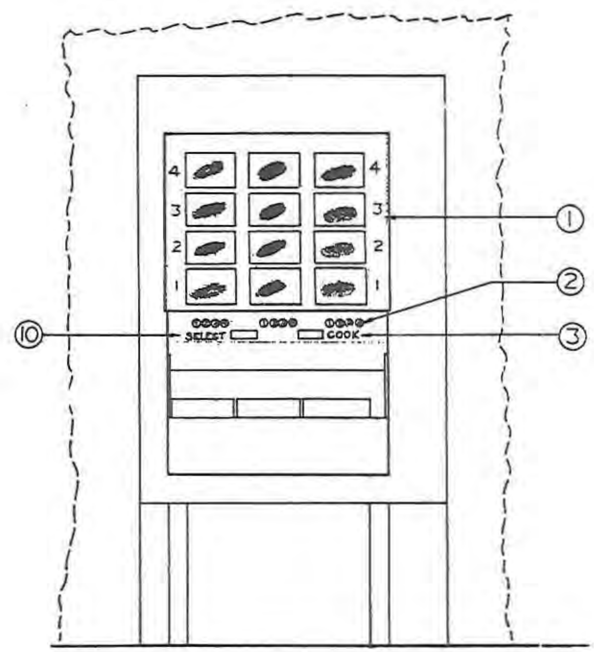
C-4. UNTENDED MEAL SERVICE GENERAL DESIGN



TOP VIEW



SIDE VIEW



FRONT VIEW

DESCRIPTION OF OPERATION OF UNTENDED FOOD SERVICE UNIT

1. Display of photos of food portions - e. i. entrees, vegetables, starches.

2. Selection Buttons - Select one item from each group of four. This control causes selection to be lifted into retrieval position.

3. "Push to Cook" Button initiates collating, heating and dispensing cycle.

4. Freezer storage stack lifts the portion selected into position for retrieval.

5. The Collator-Retriever collects one portion from each row of portions.

6. Elevator lowers packages to heating conveyor.

7. Heating conveyor advances into oven, doors close, proper microwave and/or Jet Air applied and then doors open and portions are dispensed.

8. Oven consisting of three parallel discreet units applying units of microwave and jet air surface heating as programmed by selecting button.

9. Dispensing shelf for service onto trays.

10. "Select" Button indicates when the next order can be selected. Selection can be made while previous order is cooking.

11. Position of wall if unit is installed to provide service through the wall of the dining room.

12. Freezer Door.

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